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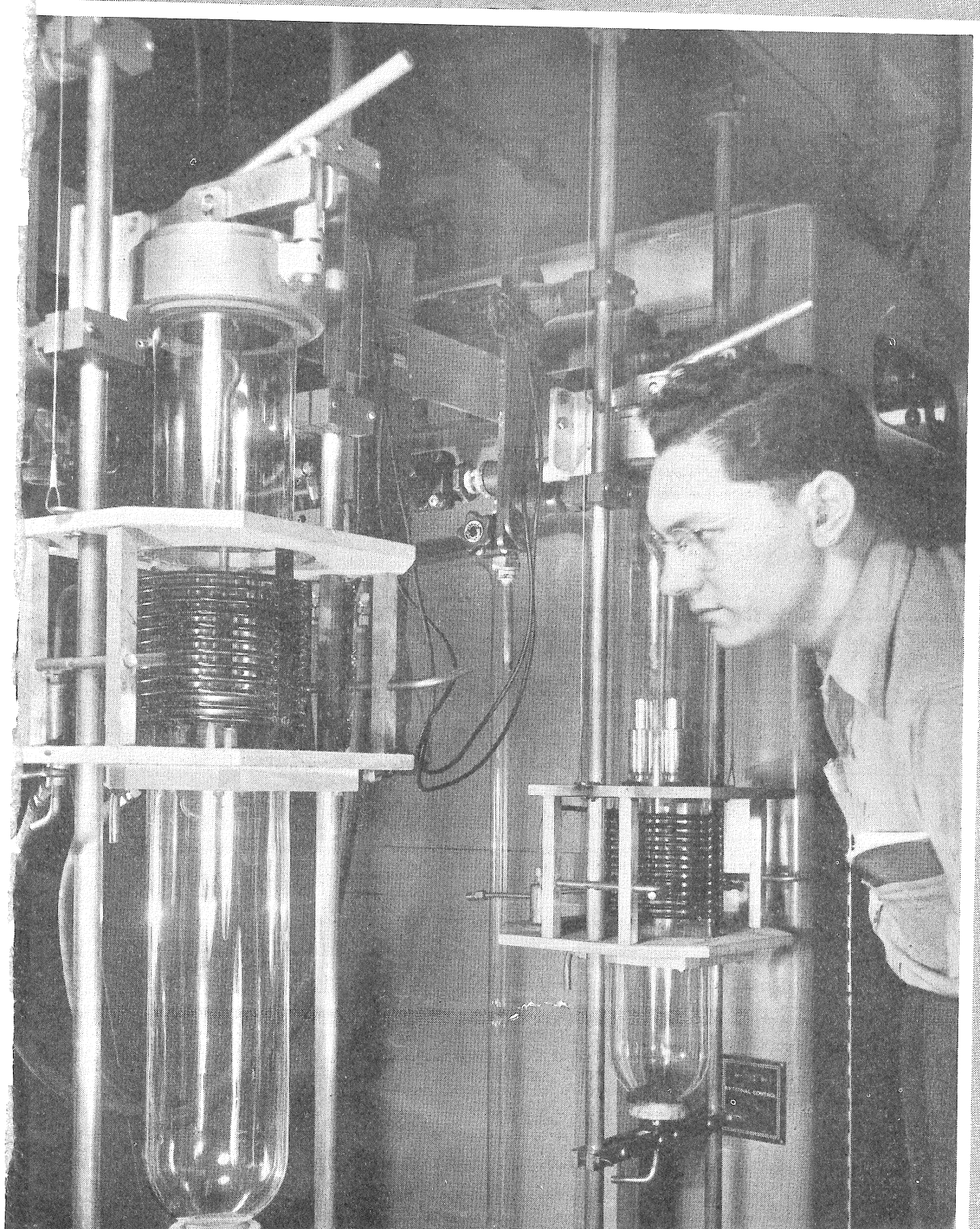
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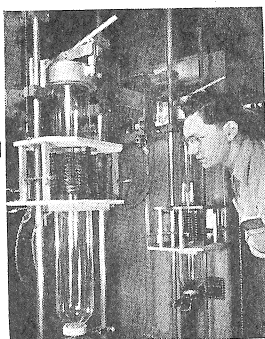
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RADIO-ELECTRONIC ENGINEERING is published each month as a special edition in a limited number of copies of RADIO NEWS, by the Ziff-Davis Publishing Company, 185 N. Wabash Avenue, Chicago 1, Illinois.

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COVER PHOTO—Courtesy of Ampere Electronic Corp.

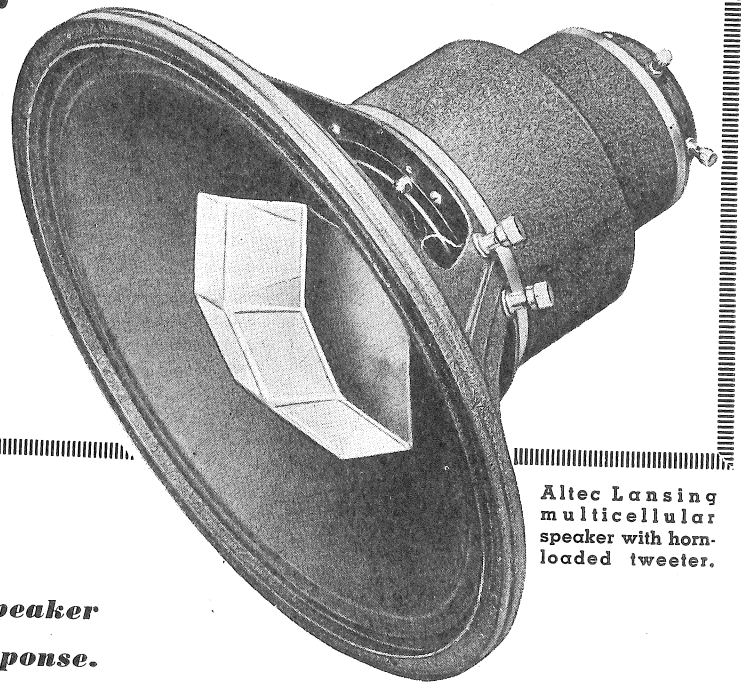
Operator watches de-gassing chamber at the plant of Ampere Electronic Corporation in Brooklyn. Metal components which are placed in the vacuum jars get white-hot when high-frequency current passes through the coils shown in the photo. This forces the metal to release occluded gas which is then drawn off by pumps.



Loudspeakers for Extended Range Applications

By **JOHN D. GOODELL**
The Minnesota Electronics Corp.

Part 1 of a 2-part article discussing speaker enclosures, efficiency, and frequency response.



Altec Lansing multicellular speaker with horn-loaded tweeter.

THIS is the first of two articles pertaining to the selection of loudspeakers and their enclosures for wide range music reproduction.

Except for the air itself, the loudspeaker is the final link in the chain between the recorded or broadcast signal and the ear. The performance of a loudspeaker is greatly dependent upon the characteristics of the air masses which must be moved in alternate compressions and rarefactions to generate an acoustic waveform. A loudspeaker is affected not only by the air it must move in its forward excursions, but also by the air masses behind it. The front and back waveforms are 180° out of phase, hence are capable of cancellation if the wavelength is such that the compression of one coincides in space with the rarefaction of the other. This, of course, is the reason that a baffle is necessary for low frequency reproduction.

The hasty conclusion may be reached that an infinite flat baffle, such as a wall, is the ideal mounting for a loudspeaker. It is true that cancellation of low frequencies by the front and back waveforms is eliminated by such mounting. A basic difficulty results from the fact that the air is a poor, tenuous transmitter of mechanical energy. At low frequencies the largest practical loudspeaker cone simply is not capable of efficient generation into a large, loose mass of air.

Compare the area of a 15" loudspeaker cone with a bass viol, a tympany, or the sounding board of a piano! In the tuba a resonating air column is used to produce efficient en-

ergy transfer, but the air column is re-tuned by the valves for notes played at widely different pitch. Such expedients, when used to increase bass response from loudspeakers, are likely to create a "one note" boom instead of clearly defined pedal tones.

The effect of acoustic amplification obtained by the use of resonators has been achieved in elaborate systems for purposes of smoothing the frequency response characteristics of loudspeakers, but the method is clumsy and inadequate at best.

Loudspeaker motors function most efficiently when they are working into a column of air, generally exponential in shape, that serves to match the relatively high impedance of their moving elements to the low impedance of the surrounding air. Such a horn may be thought of as analogous to an acoustic output transformer. This applies to high frequencies as well as to low frequencies, which introduces problems in dual speaker assemblies which will be discussed later. Horn-loading of low-frequency speakers has its primary purpose in the increased efficiency of energy transfer. With high-frequency motors the primary purpose is often one of distribution.

There are two basic reasons why cone-type loudspeakers radiating directly to the air are used in such large numbers. Both are matters of economy—one with regard to space, the other with respect to cost. Such speakers mounted on flat baffles will cover the mid-frequency range so as to include the ingredients of intelligible speech and the fundamental frequencies of most orchestral instruments.

The very high and very low frequency ranges cannot be covered with comparable efficiency with this type of speaker operation. If the vibrating system is large enough for efficient operation at the lower middle frequencies, its mass will be such that excessive energy input is necessary at high frequencies. Increasing the relative high frequency drive is not a satisfactory solution, as indicated in a later section. Low frequency reproduction is limited in efficiency by the poor acoustic impedance match.

Fortunately for the simple and inexpensive design of average home radio-phonographs, the quality of reproduction with a limited mid-frequency range is observed by the ear as being reasonably satisfactory, particularly where the loudness level is low and the balance is correct. This is due in large part to the variations in frequency response characteristics of the ear at various loudness levels. The fact that the perceptible range becomes increasingly shorter at lower loudness levels is of considerable value in achieving satisfactory compromises. The success of the Dynamic Noise Suppressor invented by Hermon Hosmer Scott is partially a function of this effect.

There is one important semantic problem in the discussion of frequency ranges. The musician and the layman usually think the upper fundamentals from 500 to 4000 cycles per second as "high," while the engineer speaks of frequencies in terms of the spectrum above the range of musical notation. Inexpensive table model sets cover the melodic range of most music quite

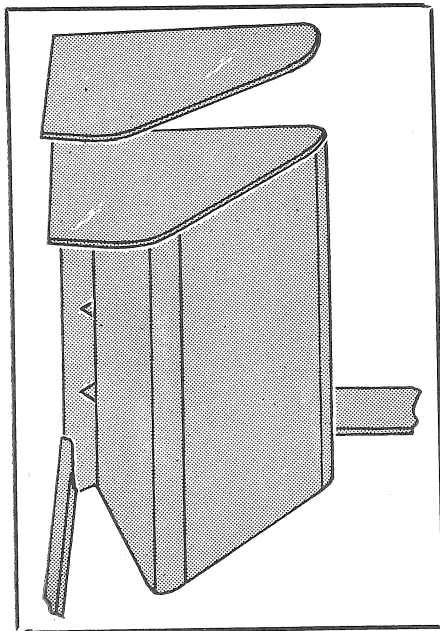


Fig. 1. Corner type horn, occupying only 15 cu. ft., with frequency range from 30 to 500 c.p.s. The space above the horn is a mounting space for a high-frequency horn.

satisfactorily. The advantage of wide range systems is largely a matter of reproducing the *quality of tone* produced by various instruments. The difference in instruments playing the same fundamental musical note is observed in terms of the attack and decay of the waveform, as well as the harmonic content. The proper functioning of the loudspeaker system is

important in all of these considerations.

The appreciation of music involves emotional and intellectual reactions. As is doubtless true of all art forms, the degree of appreciation is largely a matter of the quality and quantity of education. Full appreciation of quality of tone (timbre) is generally achieved only after a good deal of listening by an inquiring observer. This is related to the graphic arts where it requires attainment of considerable understanding to enjoy and appreciate "quality of line" in a drawing. This paragraph has been included to indicate one of the major reasons that a cross section sampling of the public taste almost never results in an indicated strong demand for wide-range reproduction. Engineers often approach this on the basis of listening for wide-range reproduction simply because they instinctively reject any suggestion that limits the scope of their efforts toward perfection. Obviously the most desirable reproduction would be indistinguishable from the original. The knowledge necessary to produce practically perfect reproduction of music is available. The limitations are usually practical matters of cost and size.

Multiple-speaker units are a definite requirement of truly wide-range reproduction. Since the high-frequency limitation is indicated as being one of mass, it is necessary to reduce the

physical size of the vibrating system for high-frequency reproduction. Low-frequency efficiency requires a large cone and/or horn-loading to effect a satisfactory impedance match. The use of separate units for high- and low-frequency reproduction leads to a great variety of electrical and physical arrangements of units and enclosures. Several possibilities are indicated in Fig. 2, and a brief discussion of their characteristics follows.

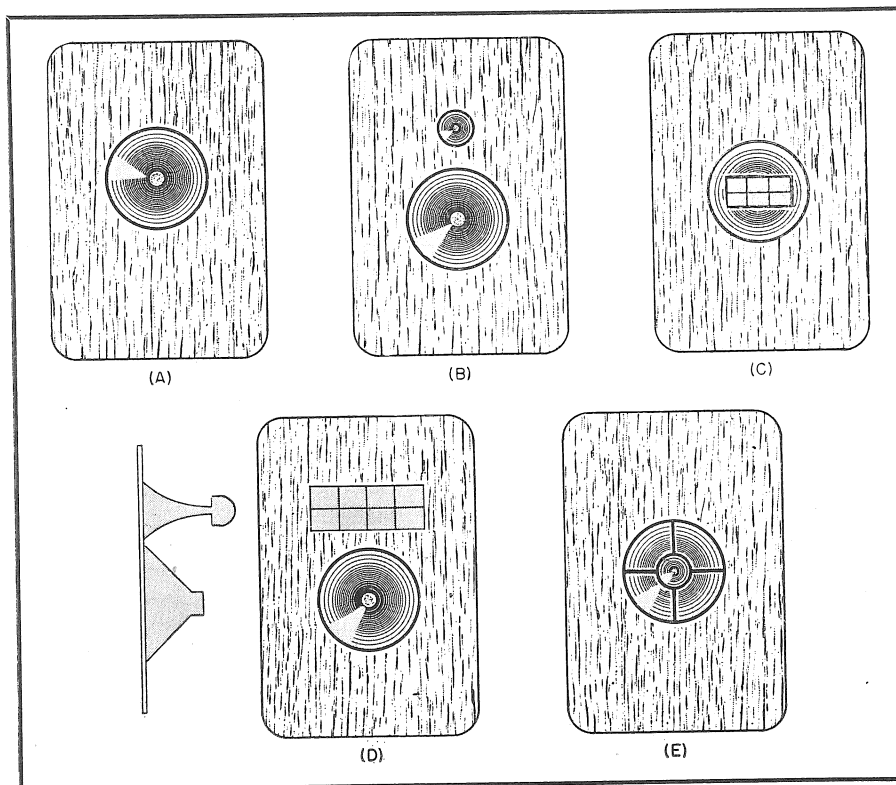
Fig. 2A represents a direct radiator cone speaker mounted on a flat baffle. A number of its limitations have already been mentioned. Another important factor is the complex breaking up of the cone surface in high-frequency generation. At low frequencies the entire cone functions as a piston, but where the wavelength at high frequencies is comparable to the cone dimensions, a different pattern exists. Assume the arbitrary figure of 2000 feet per second as the velocity of sound propagated in the cone material. If the voice coil edge-to-cone periphery measures six inches, then at 2000 c.p.s. 6 inches equals one-half wavelength and the periphery and voice coil will be 180° out of phase. Increasingly complex nodal patterns will appear at higher frequencies. The high-frequency reproduction will be seriously distorted.

Fig. 2B is the simplest type of dual speaker combination. It consists of a small cone approximately 3 inches in diameter and a large 15-inch cone. Ideally, the small unit might reproduce only a specific band of high frequencies and the large unit all lower frequencies with no overlap. An electrical dividing network to accomplish this is not practical. In the inevitable overlap portion of the spectrum, cancellation will take place whenever rarefactions from one speaker coincide in space with compressions from the other. The result is an intricate directional pattern of nulls and peaks of intensity varying with frequency in three dimensions.

In Fig. 2D a horn-loaded high-frequency driver is substituted for the small direct radiator. This arrangement will greatly improve the high-frequency distribution, which is very poor in 2A and 2B. The directional cancellation problem will still exist, though its observable effect on reproduction may be minimized by careful selection of crossover frequencies, dividing network design and relative placement of the units, both vertically and in depth behind the baffle.

Figs. 2C and 2E illustrate coaxial arrangements of 2D and 2B. In both cases the directional pattern of cancellation is improved. An undesirable feature is that the diffraction around

Fig. 2. Various speaker combination arrangements. (A) Single-cone direct radiator. (B) 3" tweeter and 15" woofer—both direct radiators. (C) Coaxial arrangement of (D), a horn-loaded tweeter and direct radiator woofer. (E) Coaxial arrangement of (B).



the high-frequency unit and the reflection from the low-frequency cone have a tendency to produce uneven high-frequency characteristics. In Fig. 2C an additional problem arises involving the difference in path length between the low- and high-frequency generators. This may be minimized by close physical coupling of the driving motors and the use of a shallow wide-angle cone for the low-frequency unit. By careful design and apportioning of the critical dimensions, a very smooth frequency response distribution and directional characteristic may be obtained with this design. The *Altec Lansing Model 604 Duplex* illustrated on page 3 is a remarkable example of achieving optimum conditions. There are a number of other factors to be discussed in this series that contribute to the quality of results from this speaker.

One of the difficulties in combining a horn-loaded high-frequency unit with a direct radiator woofer is the difference in efficiencies between the two types. Horn-loading may improve the efficiency of a loudspeaker system in transducing electrical to acoustic power by as much as 15 db. or even more, a percentage change corresponding to an increase from 2% to 30%. This effect is turned to advantage by *Altec Lansing* who provide a resistive dropping arrangement in the high-frequency section of their crossover network adjustable in steps of one db. attenuation. Acoustic absorption in rooms is characterized by poor relative damping of the low frequencies. With the *Altec Lansing Duplex*, the increased high-frequency acoustic power achieved by horn-loading permits adjustment in the dividing network to compensate for various architectural acoustic conditions.

A discussion of similar problems appears in a referenced article by H. F. Olson and J. Preston.¹ Their conclusions led to the experimental design of a two-speaker system in which direct radiator cones driven by separate motors are mounted coaxially in such a manner that the woofer cone is an extension of the high-frequency cone. Their system is termed a duo-cone loudspeaker. A complete theoretical and experimental investigation of this unit is outlined in their paper. Among the interesting results obtained is the fact that it is permissible with this system to use a crossover characteristic extending over nearly two octaves. This results largely from the fact that the two cones move essentially as a single unit in the crossover region and cancellation is not a serious problem. Furthermore, the inductance of the low-frequency voice coil is suffi-

ciently large so that the crossover network consists simply of a series low-frequency current-limiting capacitor used with the high-frequency unit. See Fig. 5.

Olson and Preston also discuss a phase inverter enclosure designed on the same basic principles as the cabinet types termed "bass reflex" by the *Jensen Manufacturing Co.* Such housings function to increase the effective bass response by shifting the phase of the back wave from the loudspeaker 180° in a low-frequency region and coupling this energy to the front wave through a port. The design is such that in certain frequency ranges the particle velocity of the air in the port will be in phase with the cone velocity and function as a supplementary diaphragm. The novel feature of the design described by Olson and Preston is the use of a port of variable size, permitting adjustment of the low-frequency accentuation.

The over-all efficiency calculated for the duo-cone speaker is approximately 10% (which is excellent), and the directional characteristics plotted show unusually smooth patterns over an angle of 90° up to 15 kc. This design would appear to be an excellent one within the limits of efficiency to be expected from direct radiator units. Olsen and Preston suggest that an average input power between 100 and 200 milliwatts is adequate for monitoring or average listening use with this speaker.

There is no doubt that horn-loading of loudspeakers increases the efficiency a very great deal. The low-frequency cutoff is primarily a function of the rate at which the cross-sectional area increases and the size of the opening at the flare, assuming that the total front-to-rear path is long enough to neglect cancellation effects. Assuming the latter factors as being perfectly designed, the low-frequency cut-

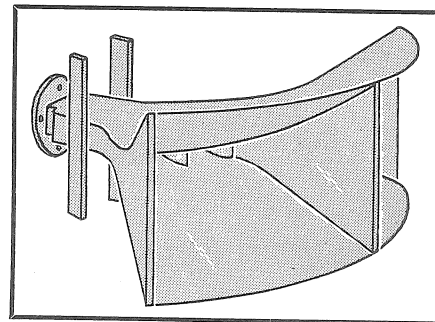


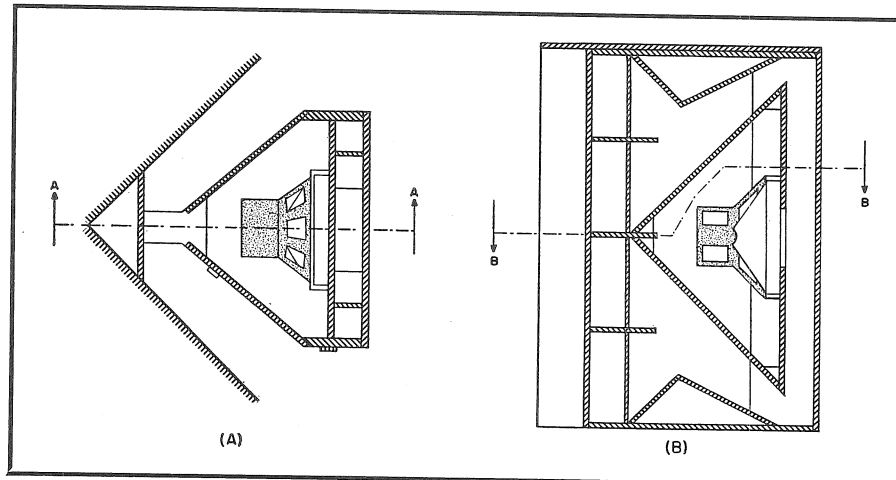
Fig. 3. Klipschorn K-5 high freq. horn.

off in any arbitrary design of exponential horn will be lowered one octave by doubling the distance in which the cross sectional area is multiplied by two. If the area doubles every 1½ inches, the cutoff will be an octave above middle C. Increasing this to 3 inches produces a cutoff at 256, six inches lowers it to 128, etc.

The second consideration is the diameter of the flared opening. If this dimension is less than a wavelength, expansion takes place abruptly and actually tends to create a suction that may effectively reflect the waveform back into the horn. If the dimension is ¼ wavelength or less, these effects will greatly diminish useful output. The generally accepted theory is that useful contribution will be made by a horn-loaded speaker down to a frequency where a circular mouth diameter would equal ½ wavelength. It is also indicated by most mathematical treatments and theoretical curves that the output below this point falls off very abruptly to zero. That such is not the case is borne out by experimental observation, and the apparent mathematical anomaly has been clarified by Klipsch.² Under any circumstances the space problem is considerable, as evidenced by a theoretical exponential horn designed to reproduce 32 c.p.s. satisfactorily. In accordance

(Continued on page 30)

Fig. 4. The Klipschorn corner cabinet with 15" motor reproduces frequencies down to 30 c.p.s., yet occupies only 15 cu. ft. Comparable theater systems require 60 cu. ft. and more.



MINIATURE TUBES for Television

THE miniature tube is synonymous with economical, efficient television receiver production. It not only permits reduction in size of the television chassis, but its operating characteristics permit broad bandwidth and improved amplification, because of higher mutual conductance and lower interelectrode capacities.

The figure of merit of a vacuum tube used in wide-band service is the ratio of its mutual conductance to the sum of the tube's input and output capacities. Mutual conductance or g_m of a tube is the ratio of a change in plate current to a given change in grid voltage or $g_m = dI_p/dE_g$.

Consequently, the g_m of a tube is the measure of how effectively a tube can convert a small change in grid voltage to a large change in plate current. Of course, the larger the plate current change per given grid signal the greater the output voltage, or plate voltage variation. Actually, in wide-band applications the output voltage is the product of the plate current change times the load impedance. This load impedance is largely the resistance of the plate load resistor in the case of a video amplifier, and the resistance of the tuned circuit load resistor in the case of a wide-band r.f. or i.f. amplifier.

In the video amplifier, which might well pass a band of frequencies from 20 cycles to 5 megacycles, the limit of the high frequency response and amplifier gain is set by the total distributed circuit capacity, Fig. 1A. This distributed circuit capacity in a well-designed amplifier is largely tube in-

By **EDWARD M. NOLL**
Temple University

The high G_m of the new miniature tubes makes them especially suitable for use in television receivers.

put and output capacity. To circumvent this loss in high frequency response, it is necessary to use a low value of plate load resistor, a value which is low in comparison to the shunt reactance of the distributed capacities at these high frequencies. However, the reduction in plate load resistance means a loss in gain at all frequencies. It is evident that to obtain any gain it is necessary to have a large plate current variation which we can only obtain from a high mutual conductance tube. It is apparent, therefore, that a high g_m tube, along with a tube having low interelectrode capacity (which means we can use a correspondingly higher value of plate load resistor per given limit of high frequency response), will give the greatest gain per given bandwidth.

In an r.f. or i.f. amplifier in wide-band service, mutual conductance and interelectrode capacity are equally important. The gain of such a stage, Fig. 1B, is determined mainly by the value of the shunt load resistor, which shunts the tuned circuit to broaden its bandwidth. The approximation of stage gain for such a stage is g_m times the load resistance. The value of the load resistor per given bandwidth is determined by the inductance to capacity ratio of the tuned circuit which it shunts. Inasmuch as the tube inter-

electrode capacity is a part of this tuned circuit capacity, the L to C ratio becomes higher when the interelectrode capacity is low. Here again the value of the shunt load resistance is set by the interelectrode capacity and its value becomes higher as the interelectrode capacity is lowered. Thus again the tube with a high g_m and low capacity gives a greater gain per given bandwidth. See Appendix I.

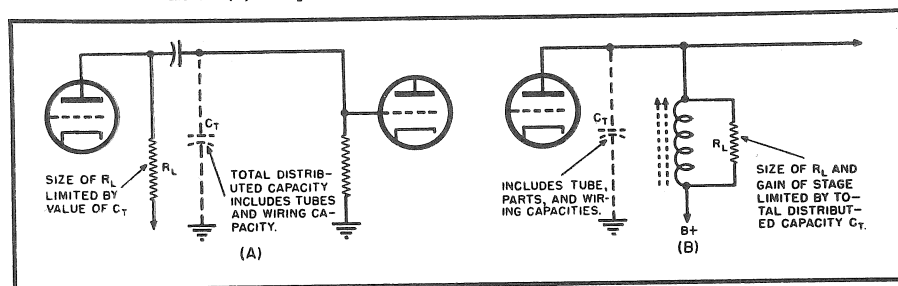
The physically small miniature tube has these characteristics: high g_m and low interelectrode capacities, as can be seen from Table I. Those characteristics of a miniature tube which make it an efficient wide-band amplifier are:

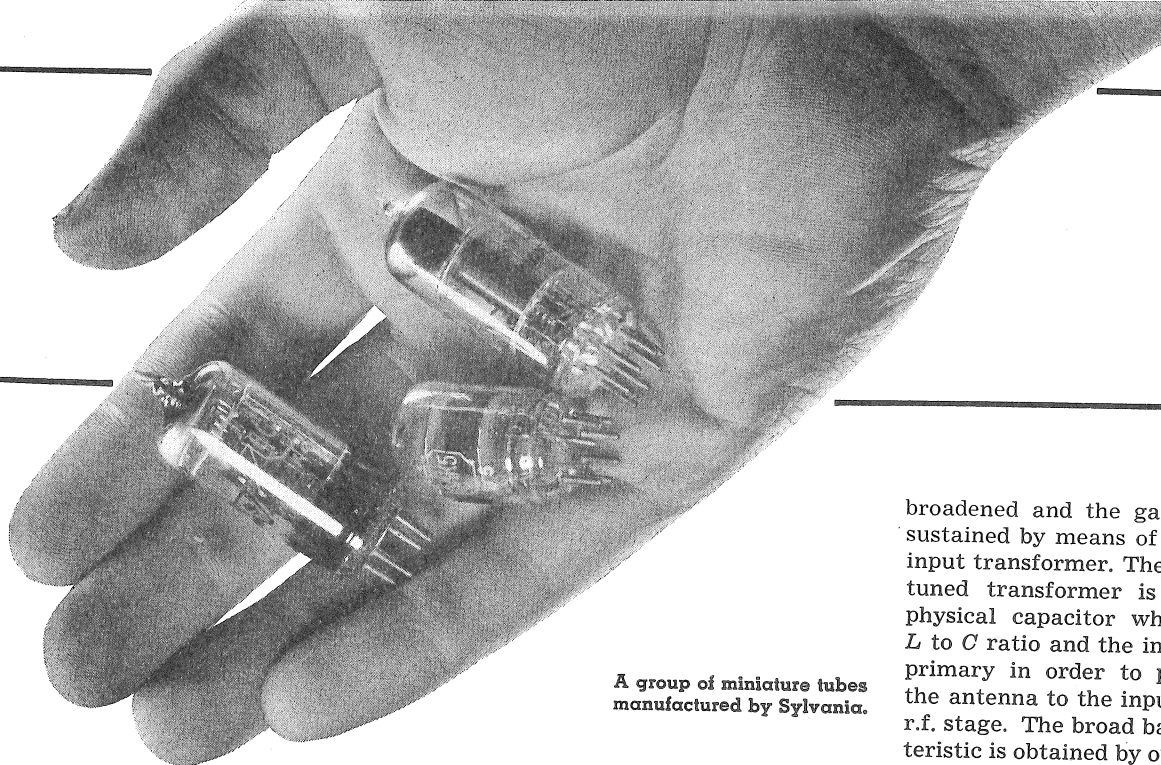
1. Physically small elements.
2. An efficient cathode and close spacing between control grid and cathode.
3. Small surface area and short leads along with ample spacing between leads coming from the individual elements of the tube.

Small physical surface means there is less capacity between elements. At the same time the control grid is closer to the cathode and exerts more control over the electron stream, therefore the mutual conductance is higher. Although the capacity between control grid and cathode increases as its spacing is decreased, the mutual conductance increases as the square of the spacing. Consequently, the figure of merit of the tube is higher, because the figure of merit is the ratio of the conductance to the interelectrode capacity. The small physical size of the elements keeps the interelectrode capacity well down beneath that of the conventional tube.

The miniature tube is also a very efficient tube at high frequencies because of its high gain to low noise characteristics. It is an inherent

Fig. 1. (A) High-frequency degeneration in a video amplifier. (B) Output circuit of wide-band i.f. or r.f. amplifier.





A group of miniature tubes manufactured by Sylvania.

quality of high frequency receivers that the dominant noise is the tube noise generated by the first r.f. amplifier or mixer. This noise is minimized in a high g_m tube because the larger plate current variations bring the signal above the noise. Thus the signal to noise ratio in a wide-band television receiver is very much higher when miniature tubes are used.

In the pre-war television receiver it was impossible to obtain an appreciable gain because of the broad band of frequencies which had to be amplified. In the new receivers, higher g_m miniature tubes replace the high g_m metal tubes, such as the 6AC7, giving a substantial increase in gain over a wide band of frequencies.

A typical r.f. stage is shown in Fig. 3. Such a stage can be an addition to a present television receiver, mounted on the television chassis or at some remote point. Its small size makes it convenient for mounting on a small sub-chassis which can be attached to the main chassis of the receiver. It is also possible to mount this r.f. box up close to the antenna termination, where it is free from noise and can amplify the weak signal being received before it is conveyed through coaxial cable to the main section of the receiver. In constructing such an amplifier, it is necessary to keep the leads short and the wiring capacity at a minimum to take full advantage of the low capacity characteristics of the tube.

To keep the L to C ratio and the gain high, it is necessary that the only capacity in the grid-tuned circuit and plate-tuned circuit is the capacity of the tube and the wiring capacity. Thus

no physical capacitor shunts the tuned circuits, which are tuned to resonance by changing the inductance of the coil. These coils are rigid air-wound coils, made from enameled copper wire. The resonant frequency is set by the number of turns of wire on the coil and, over a limited range, by spacing of the turns.

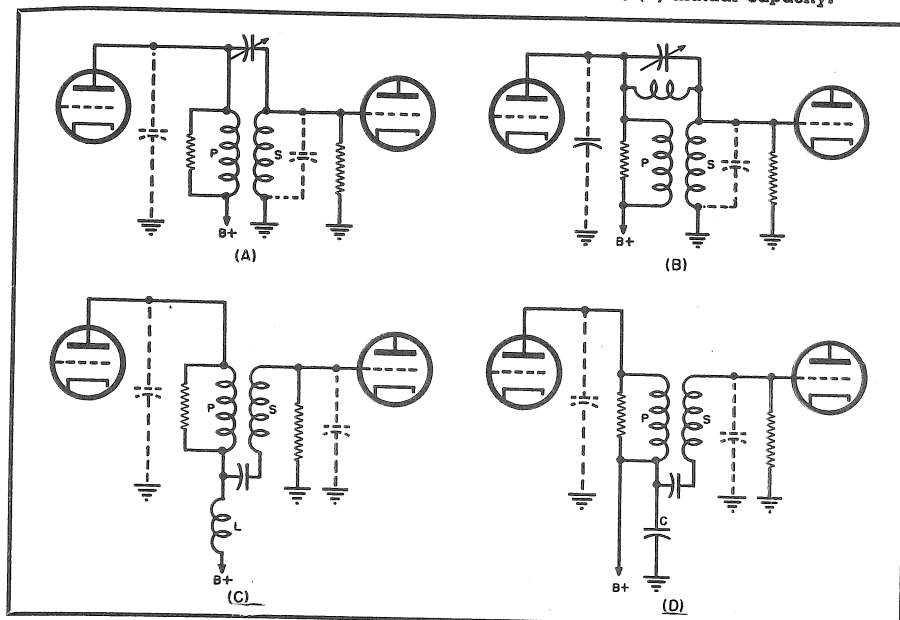
If the response of the r.f. stage is too sharp, as indicated by inability to receive the picture along with the sound, or vice versa, or as indicated by a loss of horizontal resolution, the response of the r.f. stage can be broadened, at the expense of gain, by shunting the two circuits with resistors. The bandpass of the r.f. stage can be

broadened and the gain of the stage sustained by means of a double tuned input transformer. The primary of the tuned transformer is shunted by a physical capacitor which lowers the L to C ratio and the impedance of the primary in order to properly match the antenna to the input circuit of the r.f. stage. The broad bandpass characteristic is obtained by overcoupling the primary and secondary windings of the input transformer producing a double-humped characteristic, the bandwidth of which can be controlled by the degree of overcoupling between primary and secondary windings. Overcoupling is obtained by bringing these primary and secondary windings in very close proximity to each other, possibly touching each other.

The miniature tube is also an efficient mixer and i.f. amplifier tube. The high conversion transconductance of the miniature tube produces a signal with a high signal-to-noise ratio. This is particularly advantageous when no r.f. stage is used and the antenna is coupled into the mixer.

A few broadband-coupling i.f. stages are shown in Fig. 2. These stages are

Fig. 2. Methods of overcoupling between two tuned circuits. (A) Mutual capacity, (B) mutual tuned circuit, (C) mutual inductance, (D) mutual capacity.



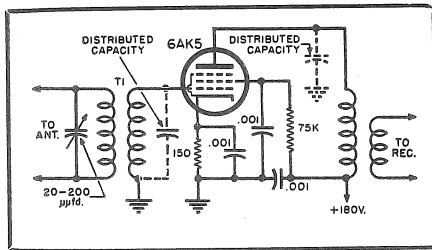


Fig. 3. Typical r.f. stage in which the transformer T_1 is overcoupled.

identical except for the method of obtaining overcoupling between primary and secondary windings to broaden the frequency response. In Fig. 2A, overcoupling is obtained by means of a small capacitor which links the primary and secondary windings. This capacity is low in value in the order of five to ten μmfd . The size of the capacitor controls the bandwidth of the stage. Bandwidth can be increased by increasing the value of the coupling capacitor.

In Fig. 2B, overcoupling is obtained by means of a tuned circuit trap. This trap is used to tune out the adjacent channel sound signal or the associated channel sound signal to prevent interference with the picture. Consequently, overcoupling is by means of mutual capacity or mutual inductance, depending on which side of the picture carrier frequency the trap is tuned. Thus the trap serves a dual purpose as sound trap and means of overcoupling.

In Figs. 2C and D, overcoupling is also obtained by mutual inductance or

mutual capacity. In each case the mutual element is located at the low impedance point of the tuned circuit and forms a part of the primary and secondary tuned circuits.

The tuned circuits resonate with the circuit distributed capacity. Fine tuning is accomplished by movable iron cores in these inductors. The values of the two tuned circuit load resistors can be determined experimentally for the desired bandwidth or can be calculated by means of the mathematics given in the Appendix.

The miniature tube can also be used as a local oscillator in the television receiver, because of its high mutual conductance and its high frequency stability. Miniature tubes can be used throughout the television receiver—in sound channels, video detectors, video amplifiers, sync circuits and sweep circuits. It is only in the power stages, such as the vertical sweep amplifier and horizontal sweep amplifier that it is advisable to use larger tubes. It is apparent that the miniature tube reduces the physical size of the television chassis and standardizes tube types. Very few television receivers will be manufactured without their quota of miniature tubes.

Two other tubes which will see wide television application are the miniature triodes 6J4 and the dual triodes 6J6. The 6J4 miniature triode is a grounded grid amplifier and the 6J6 consists of two high g_m triodes.

It is an admitted fact that the advantage of the pentode in the amplification of intermediate and radio fre-

quencies is high plate impedance, which means it will amplify a small signal voltage to a much greater extent. However, in wide-band amplification of i.f. and r.f., the plate impedance itself must be lowered in order to pass the wide band, consequently, the advantages of the pentode have been nullified. Thus, it is possible in wide-band service to use a triode with a high g_m to give approximately the same gain as a normal pentode would. An added advantage of using a triode in this type of service is that its inherent noise is much lower, because of the absence of additional grids. Another advantage of the triode in this service is its inherent lower impedance which means less severe external loading is necessary to cover a band of frequencies. In fact the triode amplifier is linear over a substantial band of frequencies without any external loading at all. This is particularly the case when a cathode-coupled arrangement is used.

A typical grounded-grid r.f. amplifier is shown in Fig. 4A. Note that the grid is grounded and the cathode and the plate are above ground, and that the stage uses a tuned cathode as well as a tuned plate circuit. Normally such a stage would oscillate; however, the grid is grounded and acts as a perfect shield between the input and output circuits. The advantages of the grounded grid amplifier areas follow:

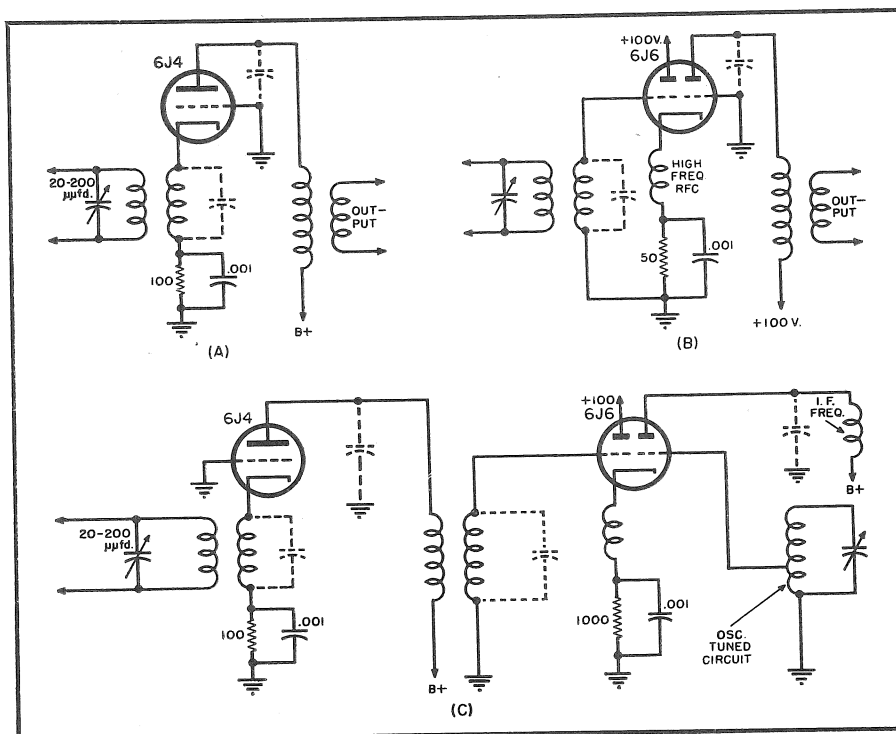
1. Low impedance and an inherently broader bandpass characteristic.
2. Low interelectrode capacities, permitting high L to C ratio and greater gain tuned circuits.
3. Low tube noises and a better signal to noise ratio.

The cathode-coupled amplifier of Szilkai and Schroeder¹, Fig. 4B, uses the two sections of the 6J6 dual triode—first section is a cathode follower, next section, a grounded-grid amplifier. The gain of this stage, although it consists of two triodes, is equivalent to the gain of a good single pentode stage. The number of component parts is approximately the same; however, the cathode-coupled stage has the following advantages:

1. Wide bandpass characteristics because of the inherently low impedance triode.
2. Low noise characteristics, because internal noise is low in a triode.
3. Low input and output capacities and consequently high L to C circuits.
4. Grounded grid connection to minimize tendency to oscillate. The coupling between the two triodes is due to common impedance of the cathode inductor which has a substantial reactance at the frequencies to be passed.

(Continued on page 31)

Fig. 4. (A) Grounded-grid r.f. amplifier. (B) Cathode-coupled r.f. amplifier. (C) Cathode-coupled mixer and oscillator.



An Unusual WAVEFORM GENERATOR

By
WARNER CLEMENTS

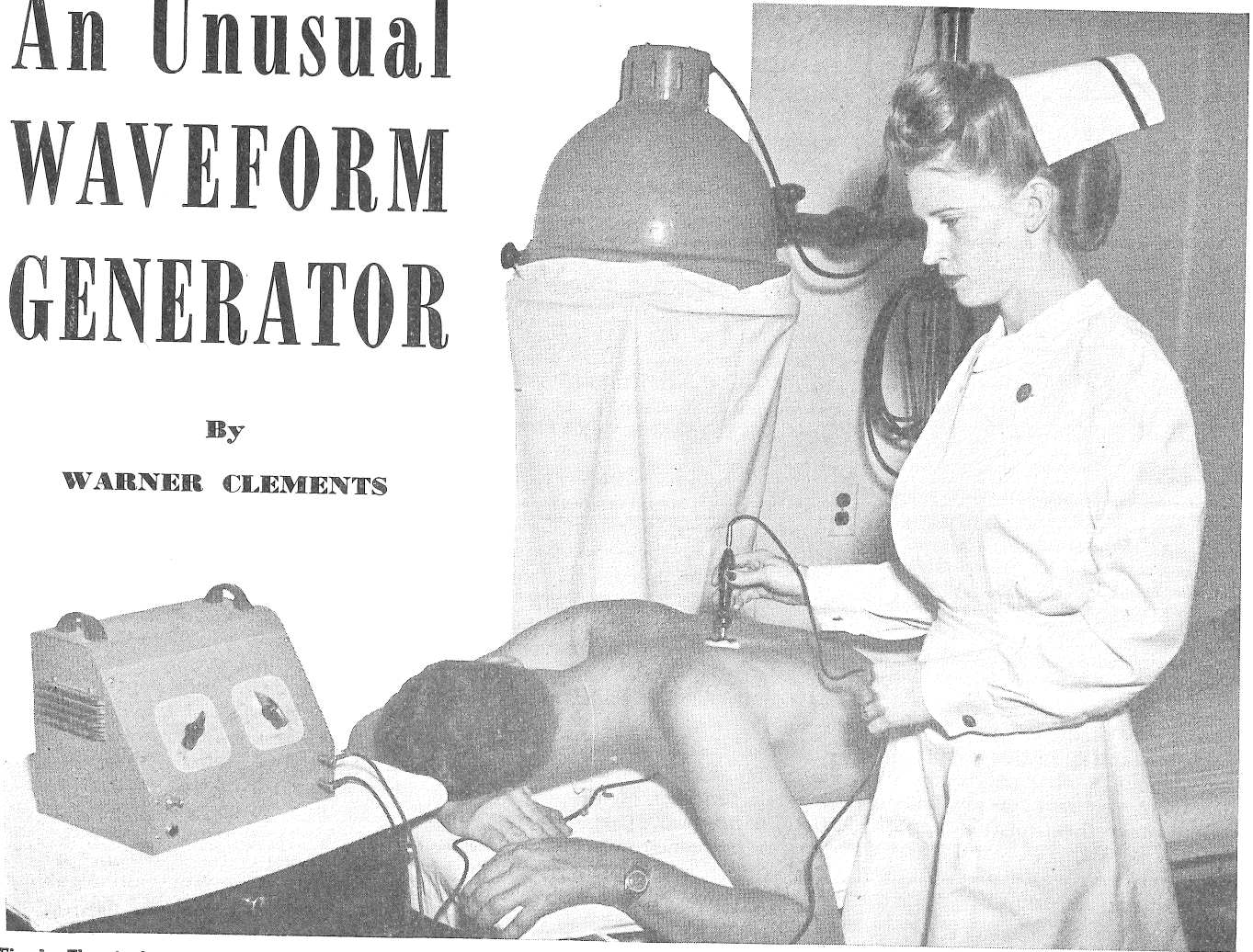


Fig. 1. Electrical stimulator in operation. It is used in the treatment of certain kinds of paralysis. Left control varies frequency, right, intensity.

Design of a low-frequency oscillator having an unusual output waveform. Waveform and voltage are variable.

RECENTLY it became necessary to design an improved generator for the waveform illustrated in Fig. 2D. The device required was to be used as an electrical stimulator for the treatment of paralyzed and partially paralyzed muscles. The waveform is known medically as a "progressive galvanic current"¹ and has heretofore been generated with the aid of a large bank of condensers, a water resistor, and a mechanically operated switch.

What made the design problem unique were the requirements that frequency and amplitude be continuously adjustable, independently of each other and of the percentage of each cycle devoted to the quiescent, or rest, period ($t-t'$). None of the conventional methods that suggested themselves for generating this waveform, such as integrating a square wave, could be made to fulfill these requirements. Also, the frequency

range to be covered, 4 to 30 cycles, presented special problems.

The circuit to be described has filled all requirements admirably. It is felt that some of the features involved could be adapted to other and diverse applications.

Oscillator

The basic oscillator circuit is shown in Fig. 3A. It will be seen that it is an adaptation of the familiar parallel inverter circuit. It differs from the parallel inverter circuit, however, in two important respects. First, the grids are not excited, not even from within the circuit. Second, the thyratron tubes used fire at only a fraction of the applied plate circuit voltage. Hence, the power output is low, but the sides of the waveform approach the linear.

The operation is as follows: Assume V_1 is fired and V_2 is about to fire. C will then be charged to the firing volt-

age of V_2 , minus the few volts drop across V_1 . When V_2 fires, the plate of V_2 will drop instantly to close to zero potential and the plate of V_1 will be driven far negative, extinguishing V_1 . At this point, C is in the position of a negatively charged condenser which is connected to a positive source, through resistor R_1 . The charging rate will be effectively the same as if the negative charge were added to the voltage of the positive source. C charges exponentially until the plate of V_1 reaches firing voltage. V_1 fires, extinguishing V_2 , C charges in the opposite direction, and the cycle is repeated.

This action is shown diagrammatically in Fig. 2. For some purposes, waveforms of the type in Figs. 2A and 2B might prove useful. In the stimulator, the two are combined so as to produce a wave of the form of Fig. 2C. If a sharp transient pulse on each peak should be desired (as a marker, for instance), it can easily be produced by the inclusion of a resistance at the point marked "X" in Fig. 3A. Conversely, to prevent such transients, the resistance from plate to plate should be kept as low as possible. For strict linearity of the sloping portions

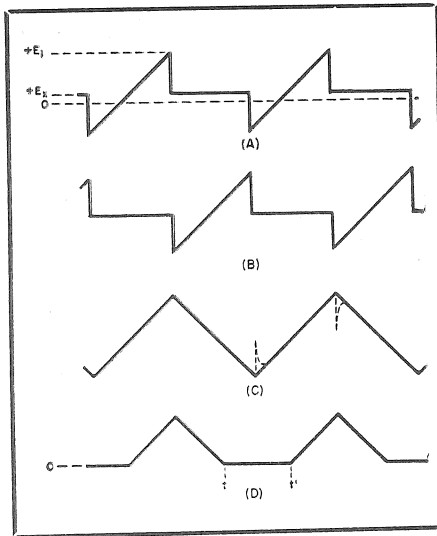


Fig. 2. Waveforms generated in the stimulator. (A) and (B) show plate voltage drops across V_1 and V_2 , respectively, and C is the result of combining (A) and (B). (D) shows same waveform after clipping.

of the waveforms, resistors R_1 and R_2 may be replaced by constant-current circuit elements (such as pentodes).

Thyratrons of the 884 and 885 types are unsatisfactory in this circuit. The same dynamic characteristics that make them excellent for sawtooth oscillators make them unstable in other applications. Many glow tubes and all power thyratrons will work well, provided that proper circuit constants are used.

The circuit may be used successfully over a wide range of low and very-low frequencies. The lowest frequency obtainable depends only on the size and quality of condenser used (C in Fig. 3A). There is an upper limit to the values that may be used for resistors R_1 and R_2 , as a certain minimum current, in the order of microamperes, is required through the tube which is fired, in order to maintain the arc. In general, the performance at very low frequencies is superior to that of sawtooth gaseous-tube oscillators. It is significant that there is no sudden high-current discharge through either tube, nearly all the power used being dissipated in R_1 and R_2 .

Higher Frequency Operation

The factors affecting the upper fre-

quency limit of the operation of this circuit become evident from a study of Fig. 3B. The approximate equivalent circuit is here represented at the point in the cycle where V_1 fires and extinguishes V_2 . r_n represents the incremental anode resistance of the gas tube while fired and C_p is the capacity (interelectrode plus stray) from the anode of V_2 to both sides of the power supply. E_i and E_e represent the ignition and extinction voltages, respectively. The firing of V_1 is indicated by the closing of the switch S .

It can be seen that, in order to return V_2 to the control of its grid, it is necessary that point "a" be made negative with regard to point "b". This is accomplished initially with almost any circuit constants. However, deionization is not instantaneous,² and condenser C starts charging immediately. If, at any time prior to complete deionization, the anode voltage on V_2 should overtake the likewise ascending value of the voltage necessary to re-ignite the tube, extinction cannot be completed. Then oscillation cannot be maintained, as both tubes remain fired.

Under these circumstances, a certain maximum rate of charge (dE_C/dt), an inverse function of the deionization time, is imposed. This, of course, limits the frequency obtainable. Deionization time, in turn, depends upon the anode current flowing at the time the anode voltage is removed. So decreasing the values of R_1 and R_2 beyond a certain point, in order to obtain higher frequencies, is doubly unprofitable. It increases the power consumption uneconomically and it increases the deionization time.

Up to this point, the high frequency considerations have been somewhat analogous to those encountered in sawtooth gaseous-tube oscillator circuits. It is important to note, however, that the maximum value of dE_C/dt is a function of the negative voltage available to effect extinction (as well as of the reciprocal of deionization time). In other words, if the plate of V_2 is driven less negative, it must become positive more slowly in order to allow time for deionization. Now, if the value of C is not kept large with regard to the value of C_p , the

negative extinction voltage is seriously cut by the voltage divider formed by C and C_p (Fig. 3B). Thus, the value of C also has a practical minimum.

For much the same reason, adjusting the firing voltage of the thyratrons has only small effect on the frequency ceiling. When the value of E_i is cut, the value of $E_i - 2E_e$ drops more than proportionately, and, finally, so does the maximum permissible rate of charge. So, though the voltage to be reached is lowered, the rate at which it is approached must likewise be lowered, and the time consumed by the cycle remains nearly the same.

Actual experience with the circuit indicates that the highest practicable frequency of operation for the basic circuit is in the neighborhood of 1000 cycles. This rate could very likely be raised by circuit modifications that would alter the waveform.

While Fig. 3B is still under consideration, it might be well to explain the possible production of a transient on peaks previously referred to. Note that R_1 , C , and C_p form a series RC circuit having a time constant much shorter than that of the circuit as a whole. Consequently, when the switch is closed, the current flow which is necessary to bring the drop across C_p to its new value has ceased by the time the charging of C through the other branch of the circuit has gotten well under way. The initial current surge through C_p creates a drop across R_1 which appears as a pulse in the output, as shown by the dotted lines in Fig. 2C (if the output voltage is taken across a part of the circuit which includes R_1).

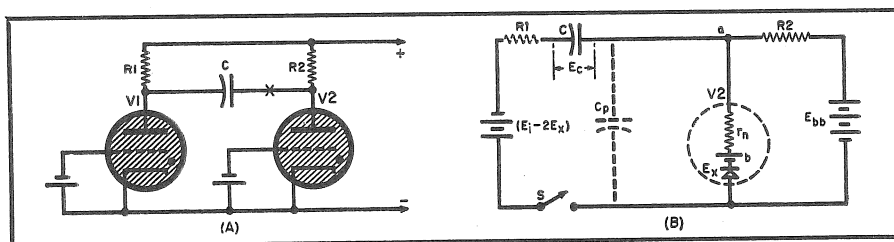
The effect is as if a small inductance had been included in series with R_1 . Transient analysis³ shows that C_p in Fig. 3B may indeed be replaced by a series inductance and resistance in forming the equivalent series circuit. Ordinarily, R_1 is very low, consisting only of wiring resistance and the r_n of V_1 . With normal values of C_p and at frequencies practical for this circuit, the transient will be so short as to be lost in stray capacities not shown, or in a small condenser provided for the purpose.

Application to Stimulator

The final stimulator circuit is shown in Fig. 4. Type 2050 thyratrons are used in the oscillator stage. Bias is adjusted so that these tubes will fire at an anode voltage of 80. This provides the required output voltage, after clipping, and permits operation on a comparatively straight portion of the control curve. With 350 volts applied to the circuit, the linearity obtained is sufficient for this particular application.

Frequency is varied by means of the

Fig. 3. (A) Basic oscillator circuit. Gas-filled tubes fire at less than supply voltage. (B) Equivalent circuit for extinction of V_2 by firing of V_1 . Elements marked " V_2 " disappear from circuit after ionization.



panel mounted dual control R_4 - R_7 . Since the anode current will obviously vary with the frequency setting, it was necessary that the bias voltage be made independent of the plate current in order to prevent the output voltage from varying with frequency. This ruled out the use of the usual voltage divider for obtaining bias, because of the inevitable series drop across the lower portion of the divider due to cathode current, and in consideration of the high control ratio of the 2050. Less than two volts of bias is required, however, and this amount is readily obtained from the heater supply, as shown, by means of an instrument rectifier. Bias is adjusted by means of R_1 , a semi-permanent adjustment. A slight ripple in the bias voltage is not objectionable, causing the oscillation to lock in with line frequency at all dial calibration points. Too much ripple, however, will cause the output voltage to rise at in-between settings of the frequency dial.

In order to obtain the waveform of Fig. 2C, the forms of Figs. 2A and 2B must be combined by subtraction, not by addition. The most convenient way to effect this combination is to take the output from directly across condenser C_2 . Separate power supplies are necessary, but they may be quite compact, and only rudimentary filtering is required in power supply "B". Study of Fig. 4 will show that any capacity between the power supplies is actually shunted across R_7 and R_8 . The effect of such capacity has been treated above. In order to minimize the results of this capacity, R_{14} has been included, effectively in series with it.

Similar capacity considerations, and the requirements that the circuits be ground-free, necessitated the unusual shielding arrangement on the input circuits of V_3 . Incidentally, care should be taken when checking this (or any ground-free) apparatus with high-impedance test instruments. Hum may be introduced into the circuit by way of the chassis of the test instrument and result in spurious readings.

Cathode-follower Circuits

To transform the waveform of Fig. 2C to that of 2D, the first half of V_3 is operated as a cathode-follower clipper. Most of the negative-going half of the wave is clipped against cutoff in this stage. Use of a cathode-follower permits the necessary direct coupling and preserves the linearity near cutoff. R_{11} , a panel-mounted control, adjusts the output intensity of the stimulator. Note that output is adjusted *subsequent* in the circuit to clipping. The inclusion of this stage thereby permits adjustment of output voltage without affecting the percent-

age of each cycle clipped, on the one hand, or the constant voltage properties of the output circuit, on the other hand. It happens that the needed amount of clipping (40%) is secured without biasing the clipper stage. If required, however, fixed bias of either polarity could be added to alter the clipping base. This will be justified below.

The output stage is something more than a "constant-voltage" stage. It is designed to deliver a voltage, independent of load and load current, which nevertheless is proportional to the input voltage, all the way from zero to peak. The cathode-follower triode stage is ideal for this purpose.⁴ Considering total (quiescent) values only, and assuming linearity, the plate current of such a stage is given by:

$$I_b = \frac{\mu E_c + E_{bb}}{R_b(1 + \mu) + r_p} \quad (1)$$

where R_b is the load resistance, which is common to plate and grid circuits.

Let us consider E_c to be made up of two components. One of these is equal to the cutoff bias, $-E_{bb}/\mu$, and the other we will call e_c . Then:

$$E_c = e_c - \frac{E_{bb}}{\mu} \quad (2)$$

Substituting:

$$I_b = \frac{\mu e_c}{R_b(1 + \mu) + r_p} \quad (3)$$

Eqt. (3) shows that, other factors remaining constant, output current will be proportional to that part of applied grid voltage which is more positive than $-E_{bb}/\mu$. So, adding a fixed bias

to an input wave determines what proportion of that wave will be submerged below cutoff, the output being proportional only to the remainder.

The clipped and suitably attenuated wave from V_{3a} is amplified by V_{3b} . The bias introduced by the fixed drop across resistor R_{10} is adjusted to just cancel out the quiescent plate current in this stage with R_{11} at zero setting. Then the input voltage to this stage will be properly represented by e_o in Eqt. (3). If $\mu \gg 1$, Eqt. (3) may be rewritten:

$$I_b = \frac{e_c}{R_b + \frac{r_p}{\mu}} \quad (4)$$

But $r_p/\mu = 1/g_m$. Substituting in (4) and transposing,

$$I_b R_b = e_c \left(1 - \frac{1}{R_b g_m + 1} \right) \quad (5)$$

This equation indicates that, regardless of load variations, the output voltage will closely approximate the input voltage in the circuit under consideration, as long as $R_b g_m \gg 1$.

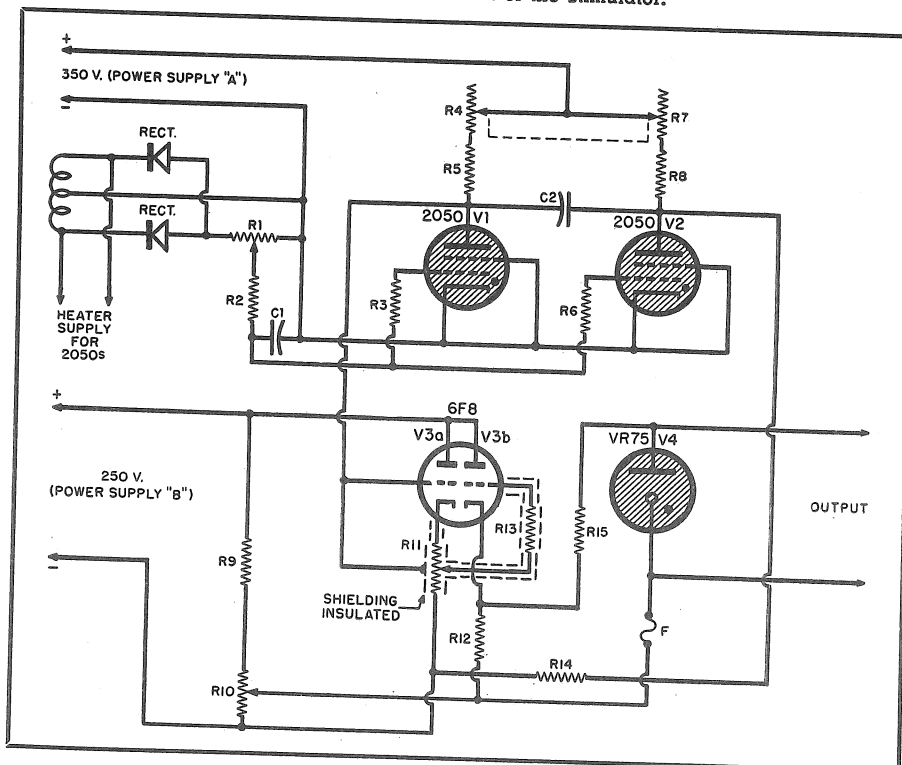
Choice of Tubes

From Eqt. (5), it is evident that the tube characteristic most effective in minimizing the effects of variation of load resistance in the output stage is the g_m . Consequently, it is desirable to use a tube with a high value of transconductance in this stage. This is not necessarily the case in the clipper stage, where the load is constant.

Of course, not only does the external load vary, but tube characteristics

(Continued on page 20)

Fig. 4. The final circuit of the stimulator.



By
FRED EBEL

*Induction furnace control
for applying equal B.T.U.'s
per unit volume of charge
processed in the furnace.*

was not enough to simply deliver equal amounts of energy to the individually heated pieces. There remained the disturbing condition of variations in bomb wall thickness which made it necessary to supply varying amounts of energy to many of the bombs.

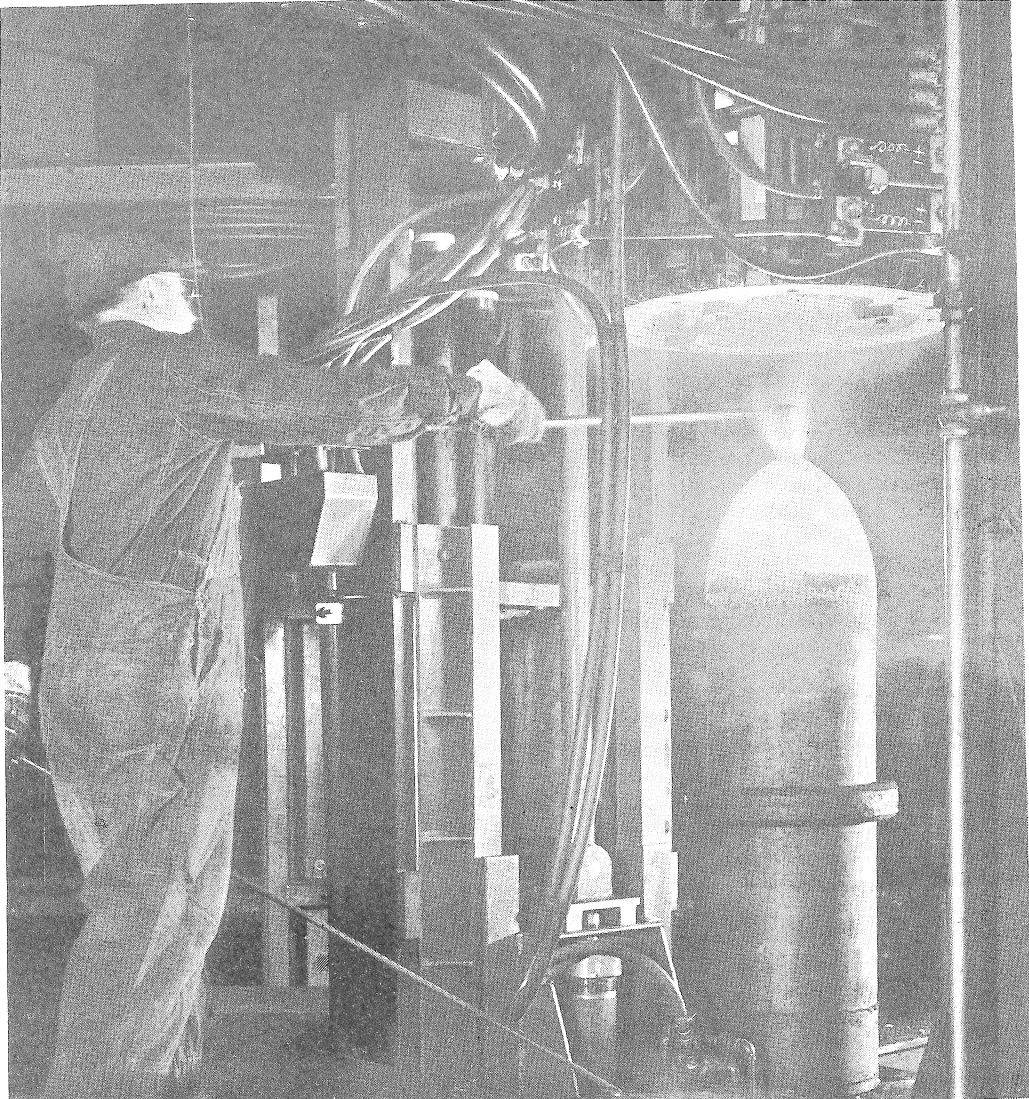
Manifestly a definite amount of energy is required to raise the temperature of a pound of steel a given number of degrees. Thus equal amounts of energy introduced into different volumes of charge result in different final temperatures.

To eliminate this unsatisfactory non-uniformity of temperature, engineers turned now to the development of a control method which could discriminate between pieces, i.e., apply equal amounts of B.T.U.'s for each unit volume of charge, even though different thicknesses of stock were fed to the furnace. Again a watt-hour meter was used, connected this time in such a manner that the speed of the disc would be proportional to the square of the line voltage.

It can be seen (Fig. 1) that the current coil of the watt-hour meter receives its power from the low potential winding of the transformer T_1 . The impedance of the current coil is so low that it presents a virtual short circuit to the transformer. Consequently the primary impedance is very low, and the current through it is determined almost entirely by the resistance R_1 . Thus the current through the current coil is proportional to the line voltage and in phase with it.

The potential coil is fed from a voltage divider formed by R_3 , PL_1 and PL_2 . This puts a voltage proportional to and in phase with the line voltage on the potential coil. The speed of the watt-hour meter disc, then, becomes proportional to the square of the line voltage.

Now, though the power integrator performed 100 per-cent in delivering the same amount of B.T.U.'s per heating cycle, it was found that some compensation was necessary for radiation



60-cycle induction furnace shown forging a bomb casing.

Watt-Hour Meter POWER INTEGRATOR

THE development of the Watt-Hour Power Integrator by engineers of the A. O. Smith Corporation of Milwaukee, Wis., is an excellent example of that adage, "necessity is the mother of invention."

Here mass production of bombs with its attendant forging operations posed the problem of temperature control.

Voltage fluctuations caused by large intermittent electrical loads of 60-cycle induction furnaces caused a great deal of interference with heating operations. And as the number of furnaces increased, the problem of voltage regulation became first on the agenda of the electrical research laboratory.

Spurred by the war's urgent demands, electronic engineers worked day and night on the problem of volt-

age stabilization. But many an idea born in the laboratory was destined to die on the production line. The use of photo-pyrometers, for example, was impractical because of the formation of interfering scale during the heating operation. And to the obvious solution of the problem—induction voltage regulators—purchasing agents reported the all-too-familiar refrain—"not available."

Engineers now attacked the temperature problem from another angle, the concept of controlling the amount of heat developed in each bomb. Practically, this suggested a watt-hour meter, and one was rebuilt so that it would indicate the amount of energy received by each forging. Though this was a great improvement over the other methods, it was found that it

losses. For when voltage was low and the time long, radiation losses increased, while with the condition of high voltage and short time, heat losses through radiation decreased.

It was to eliminate this remaining "bug" of radiation loss that the Mazda lamps PL_1 and PL_2 were connected in series with the resistors, which combination was then connected across the power line. When the voltage dropped, the resistance of the lamps became less and the percentage of the line voltage appearing across the lamps became less, and vice versa when the voltage increased. This voltage when applied to the potential coil of the watt-hour meter adequately compensated for the radiation losses.

The device, essentially a counting circuit, works in the following manner: A hole in the disc of the watt-hour meter allows a pulse of light to fall on a photoelectric cell for each revolution of the disc. Impulses from the cell trigger an amplifier which in turn advances a rotary switch a step at a time for each pulse of light. After a predetermined number of steps the rotary switch disconnects the induction furnaces from the power lines and resets itself for the next operation.

Circuit Conditions Before Heating Cycle

A more detailed explanation of the power integrator (before the heating cycle has been initiated) is as follows: Auxiliary contactor RY_1 is unenergized, RY_{2-1} is open as is RY_{2-3} . Thus the main contactor coil is not energized, nor is the potential coil of the watt-hour meter.

The current coil, however, is energized and light PL_3 is on, while photocell is dark. The grid of the 6F5 is at cathode potential. Grids of the paralleled 6L6's are highly negative with respect to their cathodes. Thus the tubes are not conducting.

The rotary switch RY_3 is not energized and switch contacts are in such a position that the moving arm of the 2nd level is on the unconnected stationary contact.

Heating Cycle Sequence

The following sequence of operations take place after the start button is pushed (operation 1).

(2) RY_2 picks up.

(a) RY_{2-2} closes, locking in RY_2 .

(b) RY_{2-1} closes energizing main contactor coil, starting heating cycle.

(c) RY_{2-3} closes energizing potential coil of watt-hour meter, causing disc to revolve.

(3) When the watt-hour meter disc revolves to a position where the hole in the disc and the photocell line up—

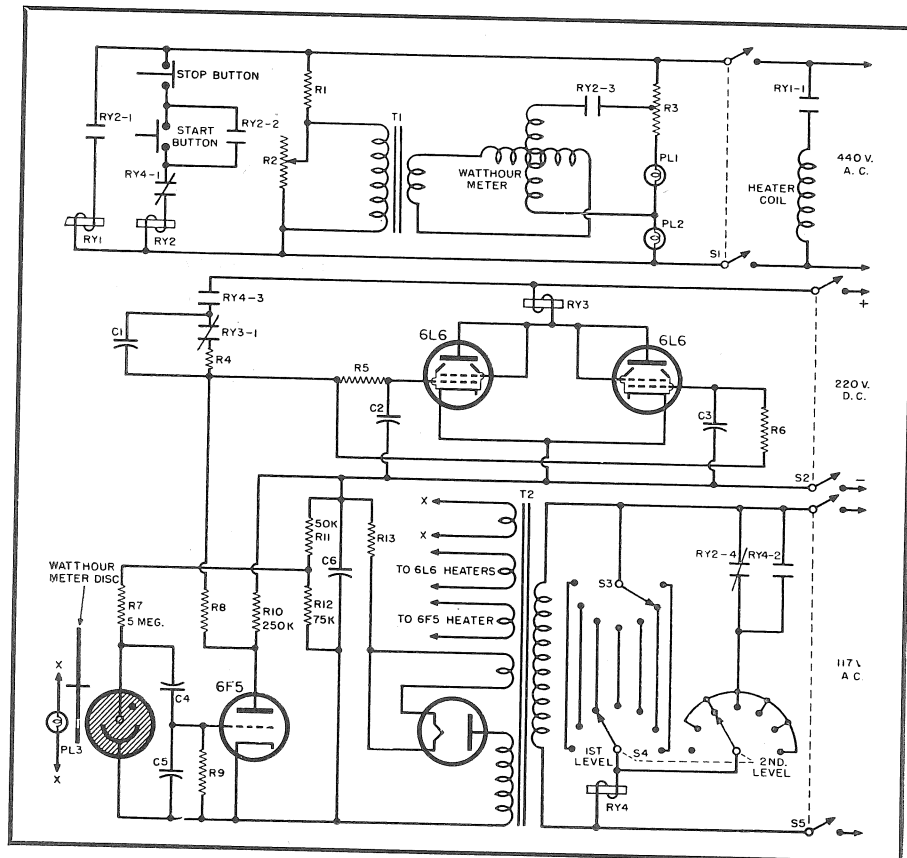


Fig. 1. Circuit diagram of the watt-hour meter power integrator.

(a) The resistance of the photocell is decreased by the pulse of light.

(b) The voltage across R_7 increases driving the grid of the 6F5 sufficiently negative with respect to its cathode to cause plate current cut-off.

(c) Voltage across R_{10} decreases to zero swinging grid bias of 6L6's to zero.

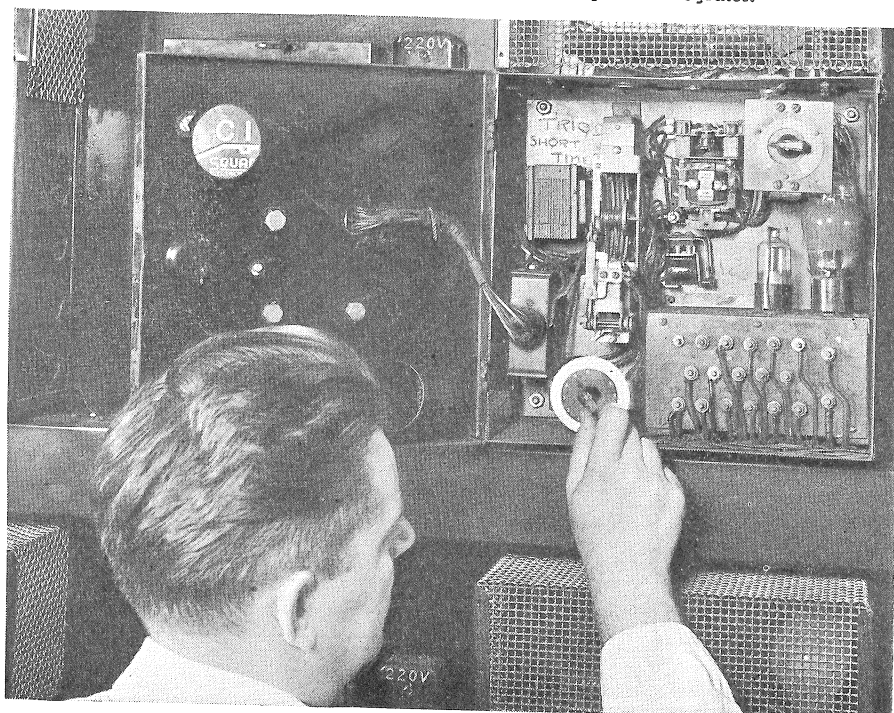
(d) 6L6's conduct, energizing the rotary switch RY_3 coil and cocking the contact shift mechanism.

(4) The hole in the disc passes the photocell.

(a) The cell becomes dark and non-conducting.

(b) The 6F5 fires causing a voltage
(Continued on page 21)

Engineer adjusting the control switch on the power integrator.



Experimental

U. H. F. FM RECEIVER

A novel push-pull mixing stage is used, having excellent noise-reducing properties.

A NEW transmitting-receiving apparatus has been developed for the experimental ultra-shortwave radio-telephonic link between the *Philips* factories in Eindhoven, Holland, and those in Tilburg, which link has been in existence for a number of years already.

For the convenience of the reader we shall repeat briefly the most important facts about the installation. For the connection in one direction a wavelength of 90.5 cm. is used, in the other direction 99 cm. The transmitter and receiver function as links in a carrier telephony system with which 48 channels can be transmitted at the same time on one pair of conductors (in this case, on one radio wave). For this purpose both the transmitter and the receiver must be able to handle modulation frequencies up to about 200 kc. For this link frequency modulation is employed. The maximum frequency swing, i.e. the

largest deviation of the frequency emitted, compared with the average transmitter frequency (332.1 mc. for one direction, 303.0 mc. for the other), amounts to 0.6 mc.

General Construction of the Receiver

The receiver works on the super-heterodyne principle. A block diagram of the most important parts is given in Fig. 3. The signal received by the aerial is applied to a mixing stage where the signal frequency is converted into an intermediate frequency of 18 mc. The converted signal is amplified and then passed through a limiter, the function of which is to suppress any amplitude modulation which may be present, especially the noise which occurs in that form. The output of the limiter is detected and the low-frequency signal obtained is amplified and then passed through a cable to the apparatus for carrier telephony in the telephone exchange,

where the 48 channels are split up and can be connected with the corresponding subscribers.

In principle this construction of the receiver does not differ from the normal receiver for frequency-modulated signals. However, it will be noted that there is no high-frequency amplifier stage preceding the mixing tube. Such a stage is in general desirable to improve the ratio between the intensity of the signal and that of the noise. In our case, however, the mixing stage has such good properties, as far as noise is concerned, that the addition of a high-frequency amplifier stage could have produced only a very small improvement. That stage could therefore be omitted, which meant a considerable simplification of the receiver.

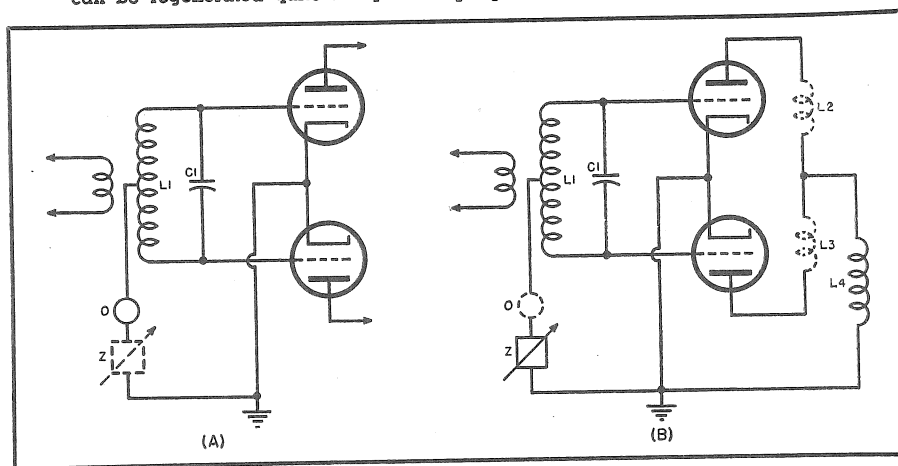
In the following we shall discuss mainly the design of the mixing stage, while the other parts of the receiver will only be considered briefly.

Principle of the Mixing Stage

Mixing in triodes

The familiar multigrid mixing tubes, generally employed for the conversion of signals on wavelengths longer than about 10 m., are no longer suitable for wavelengths of about 1 m., their special advantages being lost in this case because: 1) the shielding effect of the various screen grids has practically no result, since, due to the self-inductions and mutual inductions of the internal leads to these screen grids at these high frequencies, it is practically impossible to keep the grids free of high-frequency voltage variations; 2) the high internal resistance of the multigrid mixing tubes, seen from the intermediate-frequency circuit, means no advantage because, to amplify the large frequency bandwidths required, heavily damped circuits have to be used. On the other hand the disad-

Fig. 1. (A) The signal from the antenna is applied to the grids of the push-pull triodes. Voltage from local oscillator O is applied to grids in equal phase. (B) The "asymmetric" input circuit is regenerated by L_1 . The push-pull input circuit can be regenerated quite independently by the equal inductances L_2 and L_3 .



Condensed from an article by A. van Weel entitled "An Experimental Receiver for Ultra-Short-Wave Radio-Telephony with Frequency Modulation" which appeared in the July, 1946, *Philips Technical Review*.

vantage of all multigrid tubes—the occurrence of the so-called distribution noise caused by fluctuations in the distribution of the cathode current over the various current carrying grids—is the same with short waves as with longer waves. In the ultra short wave region, therefore, diodes or triodes are used as mixers.

The advantage of a diode mixing stage lies in the high input impedance, which makes a high step-up ratio of the signal delivered by the previous stage. However, the conversion amplification, *i.e.* the ratio between the intermediate output voltage and the high-frequency input voltage, cannot exceed unity.

When a triode is used as a mixer the input impedance is smaller than with a diode. On the other hand the conversion amplification is in general considerably larger than unity.

Further, it has been found from theoretical investigations that here a good ratio can be obtained between signal intensity and noise. These facts, together with another important advantage which will be discussed farther on, led us to employ triode mixing in the receiver in question.

Mixing in a triode is in principle accomplished by applying to the grid of the triode, together with the high-frequency signal voltage, a second voltage from a local oscillator (usually indicated briefly as the "local oscillator voltage").

The anode current then contains an intermediate-frequency component (difference of the frequencies of the two voltages mentioned), and by introducing in the anode circuit a circuit tuned to the intermediate frequency the desired intermediate-frequency output voltage is obtained.

At the high frequencies with which we are dealing here it is in general an advantage to construct amplifier and mixing stages on the push-pull principle. The following general rule is then valid: of the three voltages occurring in a mixing stage, namely high-frequency signal voltage, local oscillator voltage and intermediate output voltage, two must always be in push-pull, while the third has to be in the same phase for the two mixing systems. Because of the symmetrical dipole aerial it is reasonable to apply the high-frequency signal in balance to the converter tubes. We now apply the equal-phased local oscillator voltage in the same sense to both tubes and then obtain the intermediate frequency voltage in balance again. In that way we arrive at the diagram sketched in Fig. 1A, showing the principle of a push-pull mixing stage with two triodes. The connection of the

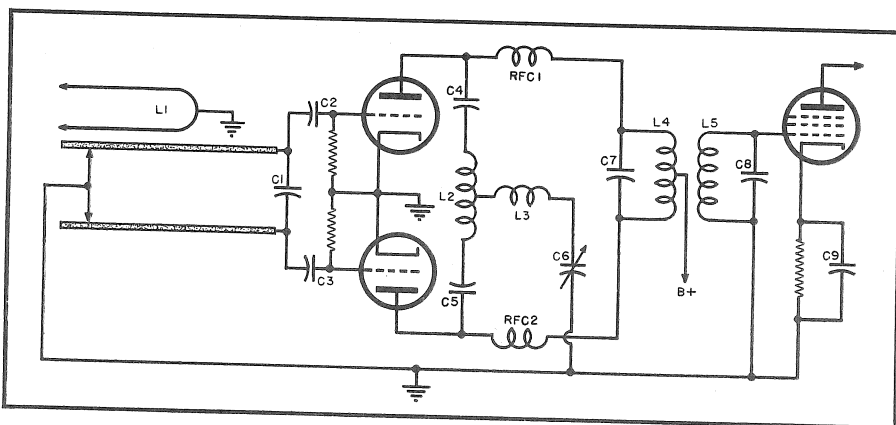


Fig. 2. Diagram of complete connections of the mixing stage.

anodes with the intermediate-frequency circuit and the source of anode voltage are omitted temporarily for the sake of simplicity. Between the control grids there is a circuit L_1-C_1 tuned to the signal frequency, which is inductively coupled with the aerial. In this way an e.m.f. in the aerial gives rise to grid a.c. voltages which are equal in magnitude but opposite in phase for the two triodes (thus balanced). Between the middle of the circuit self-induction L_1 and the earth point (*i.e.* the chassis) there is an oscillator for the auxiliary voltage, so that the latter comes in equal phase between the grids of the two triodes and the cathode, which are connected with the earth point.

Separate tuning of oscillator circuit

With such connections it is often found to be difficult to obtain a sufficiently high auxiliary voltage on the mixing tubes, due to the fact that the asymmetrical circuit (earth point—oscillator—circuit self-induction—grid-cathode capacities of the tubes—earth point) is not in general tuned to the oscillator frequency. This tuning can, however, easily be realized by

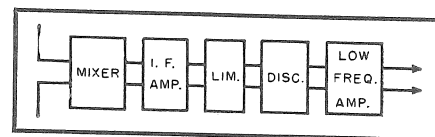


Fig. 3. Block diagram of receiver.

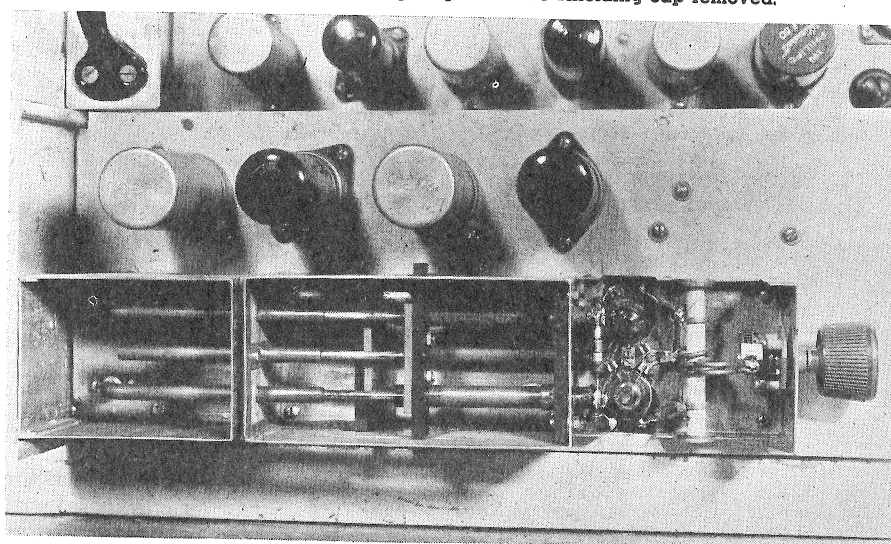
including a tuning element somewhere in the circuit. Since the push-pull circuit, tuned to the signal frequency, may not be affected by this second tuning, the tuning element should be included in a part of the circuit through which no balanced currents flow. In Fig. 1A the element in question is shown with a dotted line.

It is perhaps advisable to place some emphasis on the principle applied here: to the input electrodes of two tubes in push-pull connection two independent circuits tuned to different frequencies can be connected, *viz.* as push-pull circuit and an asymmetrical circuit. The separate tuning of each circuit can be varied with the help of circuit elements through which flow, respectively, only balanced currents or only equal-phased currents.

In order to eliminate the objection of the above-mentioned low input im-

(Continued on page 28)

Fig. 4. The push-pull mixing stage with the shielding cap removed.



TREATING STEELS By Induction Heating

By
R. A. WHITEMAN
Consulting Engineer

*Metallurgical properties of steel
and their dependence on heat treatment.*



Fig. 1. Transverse section of hardened bar. Dark area is the hardened portion.



Fig. 2. Microstructure of surface of bar at top. Surface has been etched.

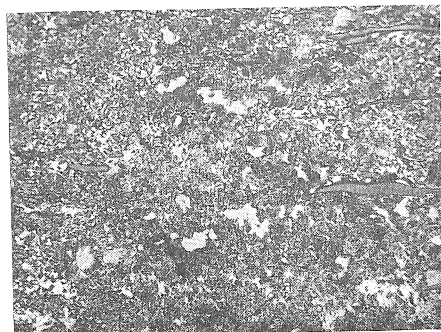


Fig. 3. Microstructure of a portion of the hardened area—etched.

THE treating of steels by induction heating is economically justified in some applications. To determine which applications could use high-frequency heating with advantage, it is necessary to be acquainted with the metallurgical properties of the steels and their dependence upon heat treatment. A correlation of these properties with the necessary high-frequency power, time and frequency will be presented in this article. Whenever any one of these electronic characteristics attain an impractical value for a particular application, induction heating may not be used with advantage.

In order to trace the properties of steel throughout a heating cycle, refer to Fig. 9 showing the iron-iron carbide relations in which iron carbide, the formula of which is Fe_3C , is the basis for study and calculations. This iron carbide is also known as *cementite*, because it seems to cement the crystals together.

Cementite is the hardest substance mentioned in Fig. 9. It is as brittle as glass and will scratch glass but not quartz. When preparing a surface for photomicrographic study, it is so hard to polish that the cementite particles stand out in relief.

Another component of steel is *austenite*, a term used for the purposes of indicating that iron exists in two or more allotropic forms. In the heat treating procedure and applications considered in this article, only the alpha (α) and gamma (γ) forms of iron shown in Fig. 9 will be traced. In general during slow cooling, but not always, alpha exists below 1333°F . and gamma above it. In Fig. 9 there is a large area designated as austenite in the solid stage.

It is well to emphasize a few of the important properties of austenite where considering induction heating

as a means of heat-treating steel. They are: (1) Its carbon content can vary from zero to 1.7 per-cent without any change in appearance under the microscope. (2) Normally, it is not stable below 1333°F . and on slow cooling transforms into other constituents near that temperature as shown below the line marked *PK* in Fig. 9. Rapid cooling can bring the transformation temperature down to room temperature. The existence of this form of steel at room temperature is rare unless a considerable percentage of alloys are present that prevent the change from gamma to alpha iron. (3) It is very feebly magnetic and cannot be picked up by a magnet. Although its magnetic permeability is greater than air it is commonly classified as nonmagnetic.

To illustrate the transformations already mentioned, consider a piece of steel of 0.83 per-cent carbon content cooling slowly and trace its changes in Fig. 9. Starting with the metal at a high temperature, even in the molten condition, as the temperature is reduced the liquid begins to solidify at about 2680°F ., passes through a mushy stage, and becomes entirely solid at 2500°F . The material is then gradually cooled down to a trifle below the 1333°F . line. At this point the atoms take on a new arrangement, passing from gamma to alpha iron. The plain crystals of gamma iron change to a structure of alternate sheets of alpha iron and iron carbide. This structure had been given the name of *pearlite* because the ridges on a polished surface diffuse light and cause it to resemble pearl in appearance. With pearlite, there is a mixture of ferrite as indicated by Fig. 9 which is made up of crystals of alpha iron and about 0.02 per-cent carbon.

In order to study the properties of steel in the vicinity of the Curie point,

refer to Fig. 9. The line A_1 represents the temperature at which gamma iron changes to alpha and A_2 represents the line above which iron loses most of its magnetism. It is important to notice that A_2 merges with A_3 , descends to the eutectoid point S , and then continues along with 1 and 3. The line A_3 represents the line where ferrite begins to separate from austenite. The line marked "Limit of Solubility, Carbide in Gamma Iron" indicates the points at which cementite begins to separate from austenite.

One of the fundamental requirements in some heat treating of steel is that of increased hardness. It is believed that hardness is caused by a strained and unnatural arrangement of atoms in steel or in any alloy. Therefore, anything that increases such strains, such as faster cooling or a greater percentage of carbon, hardens steel.

Hardness alone is seldom desired or required. The process of heat treatment is one involving both hardness and toughness with both properties controlled to satisfy the requirements of the particular case in question.

It must be remembered that nothing is accomplished in the way of hardening unless the steel is heated to a temperature that forces the carbon into solution. This means that heating to any point below the A_1 line causes no change in structure no matter how quickly the steel is cooled from 1300° F. Quenching from a temperature between A_1 and A_3 will result in some degree of hardening because some transformation has taken place. However, maximum hardness will result from a quench from about 50° F. above the line A_3 .

As an example to illustrate the effects of different rates of cooling in a qualitative way, consider a steel of 0.45 per-cent carbon. If it is heated above the A_3 line and then cooled very slowly, say in sand, the structure will be in its softest possible condition with a Brinell hardness of about 155 and a tensile strength of about 85,000 pounds per square inch. Next consider the same steel cooled by means of an air quench using a blast of air to reduce the temperature of the steel. The cooling is too fast to form the natural pearlite laminations but as a result of the faster cooling the alpha to gamma transformation has been lowered to about 1100° F. thereby producing a finer pearlite resulting in a higher Brinell hardness of about 220 and a slightly higher tensile strength of 100,000 pounds per square inch.

Finally, if the steel were given a very fast quench, say in cold water, the resultant steel would have maxi-

mum hardness. The Brinell hardness under these conditions would attain a value of approximately 550 and a tensile strength of about 190,000 pounds per square inch would be realized.

The preceding analysis of surface hardening is simple in theory but requires considerable caution and care in practice in order to obtain satisfactory results. An important reason for this is that a piece of appreciable size, say 2 inches in diameter will not cool uniformly around its surface, *unless a shallow skin is heated by induction heating*. However, if the inner layers are heated there is a continual heat transfer to the surface which will modify or even destroy the hard surface originally formed. Another reason is that quenching means and temperatures are difficult to maintain during a production run.

Note that with 0.45 per-cent carbon steel the Curie point approximately coincides with the intersection of A_2 and A_3 and therefore means that it is only necessary to raise its temperature about 50° F. above the Curie point to surface-harden this steel. This would mean that impedance variations of the load for this particular steel would not be a serious problem in high-frequency heating for surface- or skin-hardening purposes.

Upon further study of the cooling of carbon steels, it will be observed that extremely rapid quenching will yield another component of austenite called martensite which has maximum hardness of any of the other components. To understand why water quenching of some carbon steels does not produce the hardness which might be expected or superficially anticipated it is well to investigate the classical works of Davenport and Bain. Their work consisted of determining the rate of transformation of austenite at various constant tempera-

Fig. 6. Microstructure of portion of hardened area about 0.06" below surface.

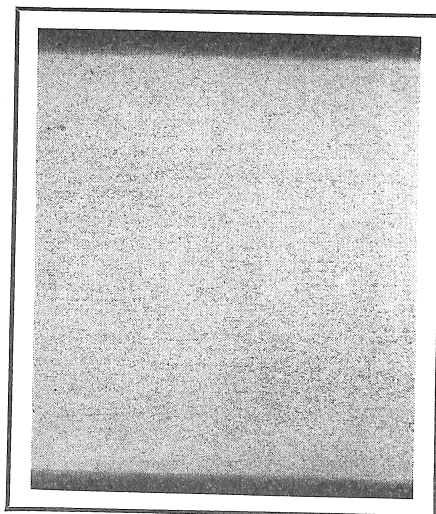
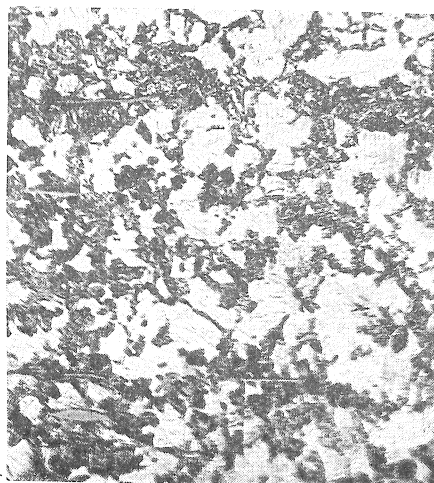


Fig. 4. Macroetched longitudinal section of the sample. Dark areas are hardened portions.

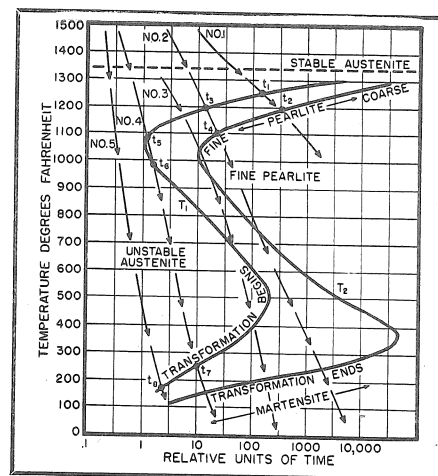
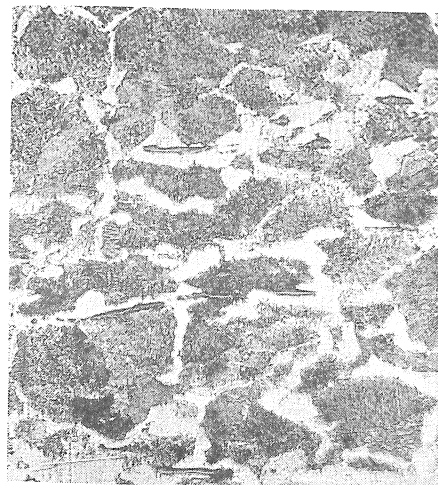


Fig. 5. S-curves developed by E. C. Bain for analyzing carbon-steel composition as a function of the quenching rate.

tures and they have summed up their results for a number of carbon steels on time-temperature graphs. Fig. 5 is a typical illustration of the trend taken by the steels studied to form the S-type curves.

Fig. 7. Microstructure of an etched portion of the core area of the sample.



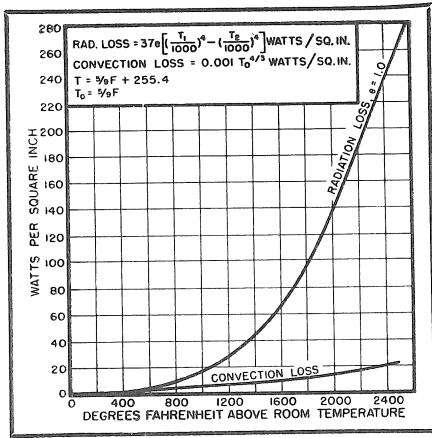


Fig. 8. Radiation and convection losses from surface in free air with an emissivity of unity.

The graphs shown in Fig. 5 should be visualized as having three time zones at any temperature level below the characteristic equilibrium temperature A_1 . These three zones are as follows: (1) the zone in which the austenite has not yet started to transform, even though it is unstable; this zone lies to the left of curve T_1 ; (2) the zone in which the transformation proceeds, at constant temperature, to

completion. This is the region which lies between curves T_1 and T_2 . Between these two curves there may be other curves representing different amounts of transformation for a specified time at any particular temperature level; (3) the zone in which the transformation is complete and the structure and the properties of the treated steel are definitely set. This region lies to the right of the curve T_2 .

Concerning the usual S.A.E. carbon steels, it is found that the curves will shift to the right with increasing carbon content. With the very low carbon steels the nose of the high-temperature, rapid-transformation zone is so close to the temperature coordinate that it is practically impossible to quench rapidly enough to suppress the transformation so that full hardening may be obtained.

In ordinary practice the transformations are produced while the piece is being cooled at some desired rate and not by causing the transformation to take place at constant temperature. The curves in Fig. 5, however, will indicate what is occurring under ordinary practice. In the cool-

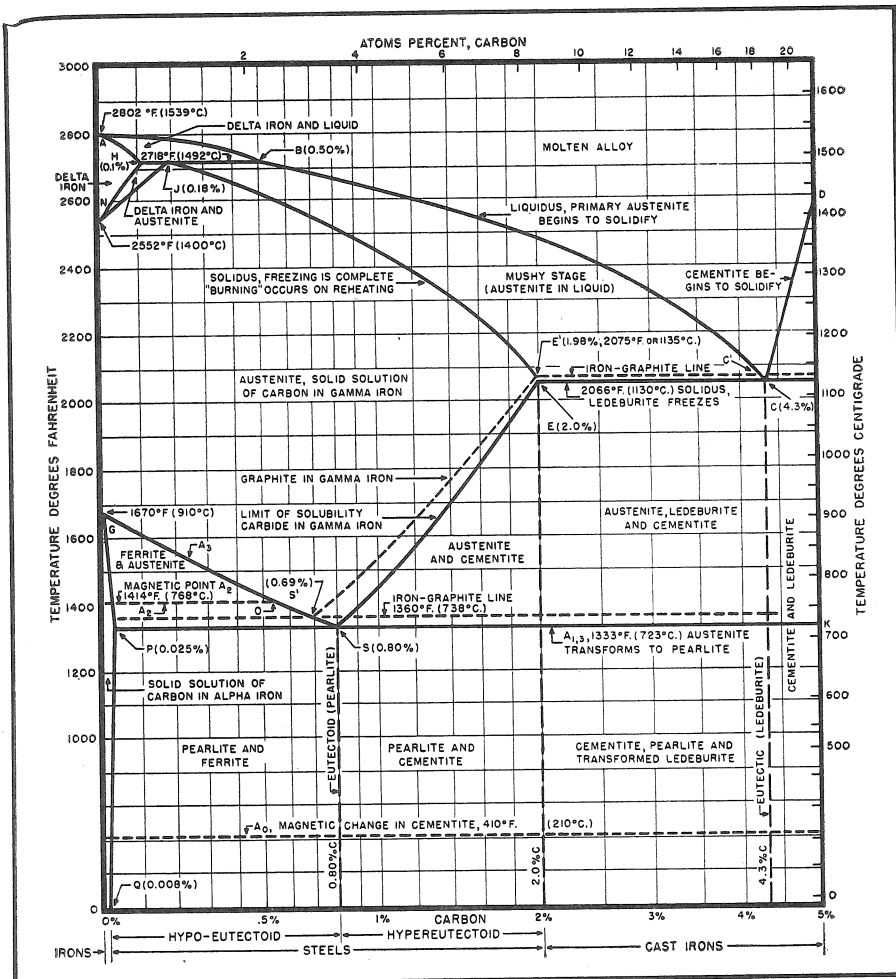
ing curve (1), which shows a very slow rate of cooling, as in annealing, the steel, on reaching temperature t_1 , on curve T_1 , will start to transform to pearlite. As the temperature drops, the rate at which pearlite forms increases, and when the point t_2 is reached on the curve T_2 the pearlite transformation is complete. Curve (2) shows an increased rate of cooling, a rate which might be expected in air cooling. The pearlite formed in case (1) will be coarse while that formed in case (2) will be fine.

When a greater rate of cooling, as in curve (5) is attempted, such as quenching in a bath of oil or water at room temperature, no transformation will take place until the temperature reaches t_3 , at which temperature and instant martensite forms. In this case, the critical cooling rate has been exceeded, so that there has been no opportunity for the rapid pearlite transformation, at 1050°F. , to take place.

At the cooling rate between curves (2) and (5) as in (4), the final steel structure will consist of a certain proportion of both pearlite and martensite. With a cooling rate indicated by (5) the surface hardness is about 60-65 Rockwell C. while for curve (4) the hardness is about 40-45 Rockwell C.

Fig. 9. Iron-Carbon equilibrium diagram. Point Q located according to J. H. Whiteley, Journal of the Iron and Steel Institute, 1936.

Courtesy of Metal Progress



The curves in Fig. 5 are the key to surface or skin hardening carbon steels by means of high-frequency induction heating. The general procedure is to first plot the S curves for the particular carbon steel under study and then determine from the graphs the rate of cooling required in order to have the cooling curve intersect the left S curve at its base assuming the quenching medium proposed for the particular steel and production method. If the ratio of the surface to the mass heated is too small, the required rate cannot be obtained and the resultant hardness will be something of the order of 40-45 Rockwell C or less instead of 60-65. This has happened in proposed programs in practice because of a misunderstanding of the problem.

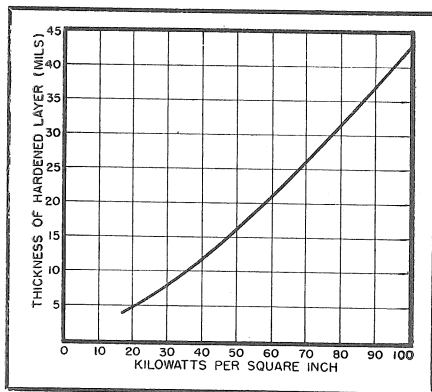
It is necessary at times to estimate the amount of heat energy lost per second from a piece of steel being heat-treated. This loss is mainly due to radiation and convection losses and can be estimated with a reasonable degree of accuracy with the aid of the graphs of Fig. 8. These curves are valuable when the heat treatment of the steel is that of preparing it for forging purposes. For this application, unlike that of surface hardening, it is necessary to raise the temperature of the steel well above the Curie point as shown in Fig. 9. It is in this

application as well as melting that the change in impedance of the load on the electronic generator changes the operating characteristics of the generator during the heating cycle. These variations in the load impedance of the generator should be reduced to a minimum by appropriate circuit design in order to obtain full advantage of the power oscillator tube in the circuit.

Since the time of heating is appreciable in forging and melting, the heat losses incurred are also appreciable and should be considered in application and design problems. At the Curie point, the radiation loss is 45 watts per square inch and the convection loss is 8 watts per square inch. At higher temperatures, however, such as 2300° F. used in forging, the radiation loss is 240 watts per square inch and the convection loss is 14 watts per square inch. These radiation losses were estimated on a basis of unity for the relative emissivity and would be less for smaller emissivities.

In order to apply high-frequency induction to steels for hardening purposes, it is of course necessary to consider the important factors of r.f. power intensity, time, and temperature as well as the rate of cooling. The logical method to use after a careful consideration of the metallurgical requirements is to increase the r.f. power concentration to the point yielding temperature gradients sufficiently steep to cause a rapid flow of heat from the surface into the metal behind it. It then becomes possible to utilize the quenching effect of the internal steel as well as the external quench. By referring to Fig. 10, the relation between the depth of penetrations, for steel above the Curie point, as a function of frequency is presented in graphical form. For comparison the depth of penetration for copper at room temperature is also indicated. In Fig. 11 will be found the

Fig. 11. Approximate power intensity required to produce skin hardening of varying depth, for air quenching.



empirical relation between the thickness of the hardened layer and the r.f. power concentration in kw. per square inch. The two graphs of Figs. 10 and 11 must be used together or the rate of cooling will not be sufficient to produce a large percentage of martensite as indicated by the curves of Fig. 5.

A number of excellent examples of proper heat treating a steel bar with the aid of induction heating are shown in Figs. 1, 2, 3, 4, 6, and 7. The microphotograph in Fig. 2 shows the medium-coarse grained martensite and dark areas of fine pearlite, known as troosite, appearing at the surface of the heat-treated steel bar. This composition indicates sufficiently rapid

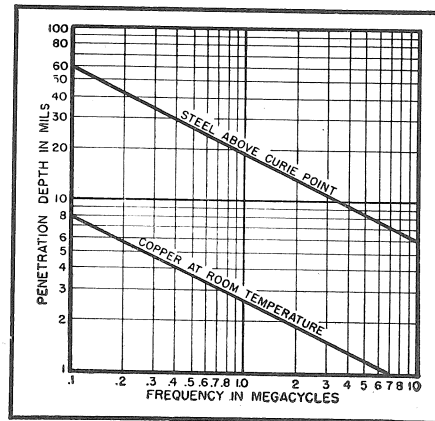
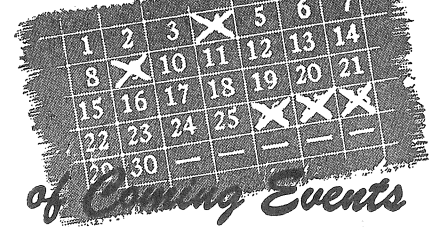


Fig. 10. Depth of penetration as a function of frequency for steel being heated by induction heating and a curve for copper as a reference.

cooling to obtain martensite so that the cooling curve would be something approximating curve No. 4 in Fig. 5. The microstructure shown in Fig. 6 was taken of the same steel bar at a depth of 0.060" below the surface with more troosite than in Fig. 2. The cooling curve for this section is that shown by the dashed line No. 3 in Fig. 5. At a greater depth such as 0.112" as shown in Fig. 3 the microstructure is close to that in the core structure consisting of a mixture of troosite and sorbite with patches of martensite. The cooling curve for this section is approximated by the dashed line No. 2 in Fig. 5. The core area, as desired, was cooled more slowly and is indicated by curve No. 1 in Fig. 5. It is observed that this curve crosses the S-curves in the region of the coarse pearlite and by cooling slowly, ferrite was formed as indicated by the chart in Fig. 9.

The heat treatment necessary to obtain these photomicrographs was performed by means of induction heating in the *Lepel High Frequency Laboratories* of New York City.

CALENDAR



MAY

3—**Technical Conference on Television**, Cincinnati, Ohio. An all-day session sponsored by the Cincinnati Section of the Institute of Radio Engineers.

11-16, incl.—**National Radio Parts and Equipment Show**, Stevens Hotel, Chicago.

17—**New England Radio Engineering Meeting**, Hotel Continental, Cambridge, Mass. An all-day session sponsored by the North Atlantic Region of the Institute of Radio Engineers.

* * *

NOVEMBER

3-5, incl. — **National Electronics Conference**, Edgewater Beach Hotel, Chicago.

3-8, incl.—**American Institute of Electrical Engineers National Convention**, Chicago.

* * *

MONTHLY MEETINGS

Institute of Radio Engineers, Chicago Section. Don Haines, Secretary, CAPitol 6500.

Dinner 5:45 P.M., Electric Club 38th floor, Civic Opera Building. Program 7:00 P.M., 6th floor, Civic Opera Building, 20 N. Wacker Drive.

May 16—Speaker and subject to be announced. Annual business meeting and election of officers.

* * *

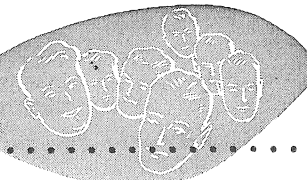
American Institute of Electrical Engineers, Chicago Section. J. E. Hobson, Secretary, 35 W. 33rd St., Chicago 16, VICTory 3300.

Supper, Ford Hopkins Cafeteria, 3rd floor, Civic Opera Building. Food served from 5:30 to 6:15 P.M.; no reservations required. Program, 7:00 P.M., 6th floor, Civic Opera Building, 20 N. Wacker Drive.

May 6 (Tuesday)—Annual Smoker, at the Furniture Club of America in the Furniture Mart. Open at 5—dinner will be served at 6:30.

* * *

Personals



Waveform Generator

(Continued from page 11)

vary with plate current, as no triode is perfectly linear. Of these, r_p is subject to the greatest variation, μ remaining almost constant by comparison. Eq. (4) shows that a good value of μ is desirable in both stages, in order to reduce the effects of variation in r_p and thus preserve linearity, particularly in the region near cutoff for the tube.

The 6F8 was a compromise selection, having good transconductance, a reasonable amplification factor, and a generous plate dissipation rating, plus the compactness of two triodes in a single envelope. For heavier loads and still better stabilized output, there are some excellent high μ power triodes that might have been used for the last stage. Were one of these selected, the natural choice for the clipper stage would be a high μ voltage amplifier triode, such as the 6SF5 or a similar tube.

The output of the completed stimulator shows less than 5% voltage variation over the range of loads normally encountered (6000 to 10,000 ohms). This figure could be improved by the use of a separate bias supply for the last stage, as a portion of resistor R_{10} is, in effect, in series with the load. The output of the device is nearly completely independent of the plate supply voltage to the cathode-follower stages, except that this voltage must be maintained high enough to prevent the flow of grid current on positive input peaks.

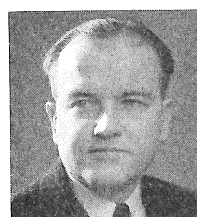
Safety Provisions

The voltage-regulator tube, V_4 , shown in Fig. 4, is included solely as a safety device. Approximately 90 volts is required to ignite this tube, while the normal maximum in the output is 80 volts on peaks. Even without the fuse shown in series with the output, a measure of protection is afforded the patient in case a plate voltage should somehow become applied across the output. The VR tube would load the power supply down until the patient could be disengaged from the electrodes. Likewise, the fuse by itself would protect the patient from a lethal amount of current. Used together, the fuse is blown instantly when the tube fires, and the safety factor is multiplied. Resistor R_{15} provides bias when the electrodes are accidentally touched together briefly, and helps prevent fuses being blown in this fashion.

Both power supplies are transformer-type, with the transformers having good insulation. Likewise, all circuit wiring and components are well



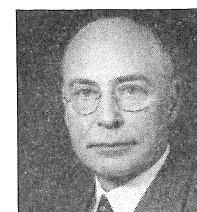
JOHN L. ABBOTT has been appointed to the post of application engineer in the industrial x-ray division of *North American Philips Company, Inc.*, New York City. Previously, he had been a senior metallurgist for *Wright Aeronautical Corporation* from 1941 to 1946. Mr. Abbott holds the professional degree of Engineer of Metallurgy and is a member of the American Society for Metals. He graduated from the Colorado School of Mines in 1941.



DR. JOHN A. HIPPLE, world authority on the design, construction and use of the mass spectrometer, will head the Atomic Physics Section of the National Bureau of Standards. In this new post he will direct research on the ionization and separation of molecules by electron impact, and the processes involved. Formerly with *Westinghouse Research Laboratories*, Dr. Hipple is a graduate of Franklin and Marshall, and received his D.S. at Princeton.



GARRARD MOUNTJOY has been named chief radio engineer of *Stromberg-Carlson*. Widely known for his advanced work on FM and television and author of numerous publications in these fields, he was previously head of the licensee consulting section of the *R.C.A.* license laboratory. During the war, Mr. Mountjoy worked on development of the Loran system of navigation and other radar projects. He is a graduate of Washington University.



CHARLES S. REDDING, president of *Leeds & Northrup Co.*, was recently awarded the honorary degree of Doctor of Science at the mid-winter commencement exercises of the University of Pennsylvania. He graduated from there in 1906 and subsequently served as a faculty member. In 1939, he succeeded Morris E. Leeds, now chairman of the board, as president of *Leeds & Northrup*, makers of electrical measuring devices and heat-treating furnaces.



WALTER A. WEISS, recently selected as supervisor of quality control for the Radio Tube Division of *Sylvania Electric Products, Inc.*, will head the formulation and execution of quality control policy and the coordination of quality control activities for the division in all *Sylvania* plants. Joining the company in 1941, Mr. Weiss became supervisor of quality control at the Emporium, Pa., plant in 1942. He is a graduate of Pennsylvania State College.



DR. VLADIMIR KOSMA ZWORYKIN has been elected vice-president and technical consultant of the *R.C.A. Laboratories Division*. Associated with *R.C.A.* for 17 years, Dr. Zworykin has headed the Electronic Research Laboratory at Princeton, N.J., and has received international recognition for his achievements. Earlier he disclosed he is directing work on an electronic calculator which may make possible accurate weather prediction and control.

insulated from the metal case. The apparatus is thus ground-free and line-free. The patient will not be endangered by touching metallic objects while under treatment, nor will the attendant himself receive an unscheduled treatment from touching the case.

Many other safety measures are desirable in a device of this kind, and have been incorporated. For instance, a heavy-handed attendant might, intending to turn the intensity control down, force it bodily over center to the highest output position. To prevent this, a rugged wire-wound control is used, and the shaft has been weakened so that it will twist off before the stops give way.

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2. Reich, H. J., "Theory and Application of Electron Tubes," pp. 398-400, 431, McGraw-Hill.
3. Frank, Ernest, "Pulsed Linear Networks," pp. 186-188, McGraw-Hill.
4. Waadelich, D. L., "High Resistance D. C. Voltmeter," *Electronics*, p. 158, March, 1946.

Power Integrator

(Continued from page 13)

drop across R_2 which places a high negative bias on the 6L6 grids.

(c) The 6L6's cease conducting, thus de-energizing RY_3 , driving rotary switch one step to the right.

This operation is repeated each time the hole in the disc passes the photocell, until the moving contact on the first level of the rotary switch reaches the last contact. This stationary contact is connected to the tap being used on S_3 .

This causes RY_4 to pick up, instituting the following sequence:—

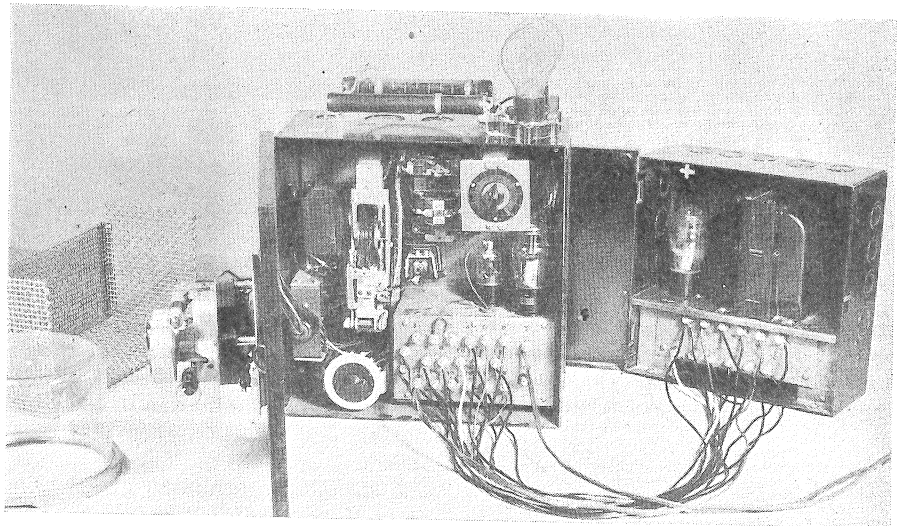
(1) RY_{4-1} opens up, dropping out RY_2 and the main contactor, terminating the heating cycle.

(2) The rotary switch resets to the original position. This operation is done as follows:

(a) RY_{4-3} closes thereby connecting the grids of the 6L6's to the positive side of the 220-volt d.c. source through resistors R_4 , R_5 , and R_6 . The grids come up to the cathode potential, the tubes conduct, and RY_3 picks up cocking the rotary switch shifting mechanism and opening RY_{3-1} .

(b) The opening of RY_{3-1} disconnects the grids of the 6L6's from the positive side of the 220-volt d.c. line, allowing the grids to go negative to the potential of the 6F5 anode. The 6L6's become non-conducting, de-energizing RY_3 , causing the rotary switch to advance one step.

(c) This is repeated until the moving contact on the second level hits the unconnected contact. This breaks



Component parts of the power integrator. Electronic counting circuit amplifier (center) with revised watt-hour meter on door. Amplifier power supply is on right.

the circuit to the coil of RY_4 causing it to drop out. RY_{4-3} opens stopping the reset action.

The circuit is now in the same condition as it was before the heating cycle was initiated.

Some of the components might demand an explanation. C_1 is included in the circuit to introduce a slight time lag in the changing of the grid potentials of the 6L6's during the reset period. R_5 , R_6 , C_2 , and C_3 act to

prevent oscillation in the paralleled 6L6's. They also limit to some extent the grid current during the reset operations.

Though the Watt-Hour Meter Power Integrator was used as an electronic temperature control in the forging of bombs, it is obvious that with a little imagination the device can be applied to many industrial uses.

The Shape and Size YOU need!

PARAMOUNT

SPiral Wound PAPER TUBES

SEND FOR ARBOR LIST OF OVER 1000 SIZES
Inside Perimeters from .592" to 19.0"
Convenient. Helpful. Lists great variety of stock arbors and tube sizes. Includes many odd sizes. Write for Arbor List today.

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Square and Rectangular Tubes

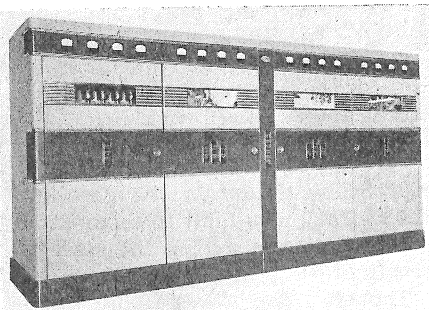
Leading manufacturers rely on the quality and exactness of PARAMOUNT paper tubes for coil forms and other uses. Here you have the advantage of long, specialized experience in producing the exact shapes and sizes for a great many applications. *Hi-Dielectric, Hi-Strength.* Kraft, Fish Paper, Red Rope, or any combination. Wound on automatic machines. Tolerances plus or minus .002". Made to your specifications or engineered for YOU.

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NEW PRODUCTS

RAYTHEON TRANSMITTER

With the announcement of two new transmitters, the RA-5, with 5 kw., and the RA-10, with 10 kw., *Raytheon Manufacturing Company's* Broadcast Equipment Division of Chicago has



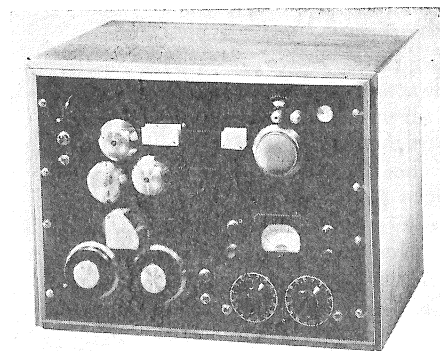
completed its AM line of from 250 to 10,000 watts power.

These transmitters eliminate all non-essentials and incorporate mechanical and design improvements specified by station engineers in a survey made by *Raytheon*. One of the features is a new flexibility of operation which allows either manual or automatic control at the centralized control panel, plus manual or automatic control through a transmitter control console.

Additional data may be obtained from *Raytheon*, 60 E. 42nd St., New York 17.

HIGH FIDELITY RECORDER

Model SD-1 high fidelity wire recorder, being produced by *Magnecord, Inc.*, is designed for professional users, with applications in radio and motion



picture production as well as in the laboratory.

Incorporating a frequency response flat within 2 db. from 50 to 12,000 c.p.s. with a signal-to-noise ratio of well

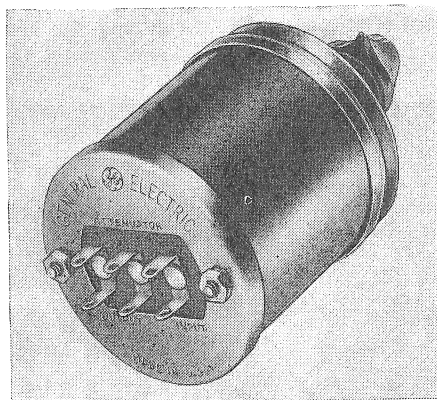
over 45 db., this custom-produced unit utilizes stainless steel wire .004 inch in diameter. A capstan drive system sends the wire across the heads at 4 feet per second. This design greatly assists in the elimination of wow and flutter and produces constant wire speed.

Additional information may be had from *Magnecord, Inc.*, 304 W. 63rd St., Chicago 21, Ill.

G-E ATTENUATORS

Attenuators with practically constant input and output impedances throughout the entire range of control, dissipating 10 watts of power at any setting, are a new addition to *General Electric Company's* line of radio parts for servicemen and distributors.

The controls' provision of linear attenuation with ample power handling



capacity plus other new features give the attenuators long life with a minimum of noise and distortion.

A specification sheet on the unit is available from *G-E's* Specialty Division, Wolf St. Plant, Syracuse, N. Y.

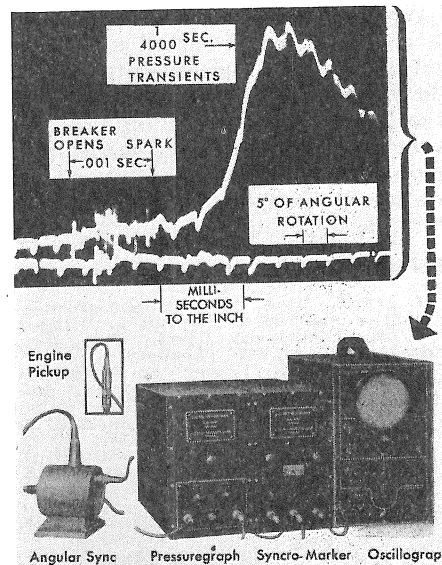
"SYNCHRO-MARKER"

A device for transmitting to the screen of a cathode-ray oscillograph an accurate picture of pressure variation related to time and speed indicators has been announced by *Electro Products Laboratories*.

Made by the producers of the "Pressuregraph," the "Synchro-Marker" embodies all the advantages of the former but broadens the field of application. To the substantially linear pressure-time curve of the "Pressuregraph" the new instrument adds a signal which synchronizes the time-base sweep of the oscillograph with

the rotation of the machine under test so that repetitive pressure phenomena will appear stationary and brilliant on the oscillograph screen.

Complete details on the instrument, which may be used in pressure-time investigations of internal combustion engines, jet engines, fuel engines, fuel

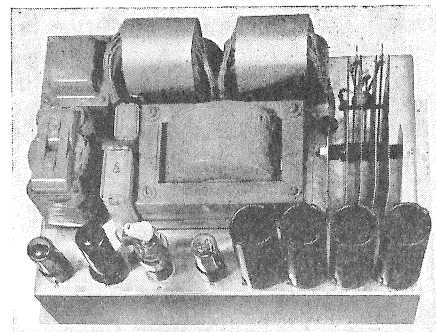


studies and displacement of moving parts, may be obtained by writing the manufacturer at 549 W. Randolph St., Chicago 6, Ill.

NOBATRONS

Nobatrons, a new line of voltage regulation units being produced by *Sorenson & Co., Inc.*, make possible d.c. voltages at currents and stabilities previously available only with batteries.

Available in 6 standard models, Nobatrons operate on a 95-125 volt a.c. source of 50 to 60 cycles and provide amperages of 5, 10 and 15 with output voltages of 6, 12 or 28 respectively. Full information may be ob-

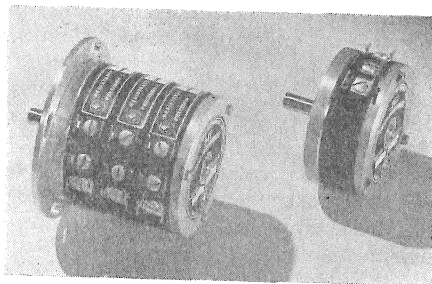


tained from *Sorenson*, 375 Fairfield Ave., Stamford, Conn.

LINEAR POTENTIOMETER

An improved design linear, wire-wound potentiometer, made by *Fairchild Camera and Instrument Corp.*, Jamaica, N. Y., is available in single

units or ganged in multiple on one shaft to provide independent voltage



outputs for several related variables.

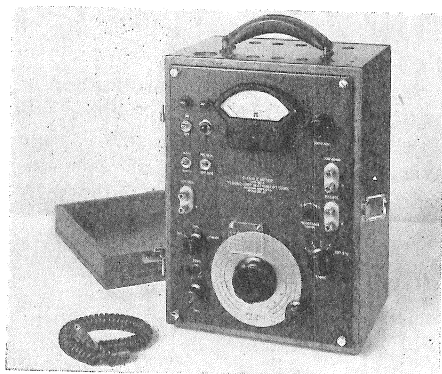
Being made in the 2-inch size as Unit No. 747 and in the 3-inch as No. 748, the potentiometer is intended for communication equipment such as transmitter controls for AM, FM, television and shortwave; servo mechanisms; instrument controls and attenuator in industrial equipment, and industrial x-ray and electronic heating equipment.

Z-ANGLE METER

Designed for impedance and phase angle measurements over a frequency range of 30 to 20,000 c.p.s., Type 310-A Z-Angle Meter is being produced by *Technology Instrument Corp.*

Applications include measurement and rating of loudspeakers, microphones, transformers, transmission lines, amplifier input and output impedance, phonograph and vibration pickups, and in general any network containing electrical or mechanical resonances.

A further application in the electrical or radio laboratory is the measurement of impedance of by-pass circuits or checking of by-pass condensers,



without the necessity of disconnecting the condensers from the circuit.

A bulletin describing the instrument may be obtained by writing the company at 1058 Main St., Waltham, Mass.

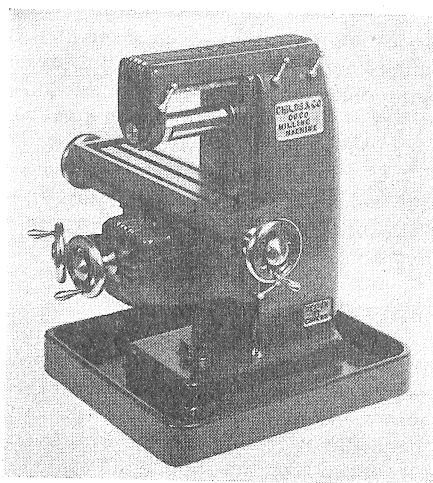
MILLING MACHINE

Designed to fill the need for a small, low-cost, accurate and sturdy miller, Model No. 0000 Knee Type Milling

Machine is being manufactured by *Childs and Co.*

The 14½ in. high basic unit illustrated may be used for bench or table model operation or, when used with the pedestal base, offered as an accessory, provides a floor-type milling machine. A countershaft and jack-shaft with V-belt pulleys provide nine changes of speed. The countershaft assembly, which is available in the pedestal base, provides speeds from 280 r.p.m. to 11,150 r.p.m.

Longitudinal feed is 6 in., trans-



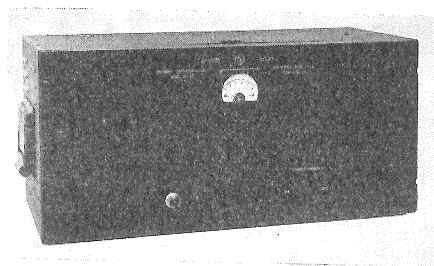
verse feed is 1½" and vertical feed 4".

Descriptive literature may be obtained by writing, *Childs and Co.*, 249 16th St., Conneaut, O.

CAPACITANCE RELAY

A sensitive capacitance relay, Model DD-20, being made by *Browning Laboratories, Inc.*, of Winchester, Mass., enables changes in capacitance to con-

trol external devices or circuits. A panel meter indicates capacitance

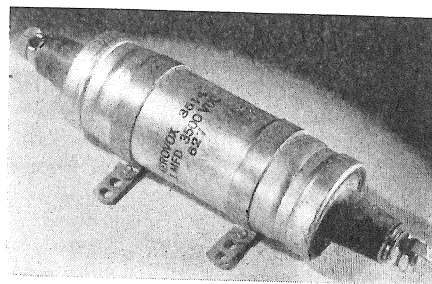


changes in addition to relay operation.

The instrument may be used in the control of machinery where direct contact with machine or material is undesirable, safety control for machine operator, or limiting of linear motion.

HIGHER CAPACITOR VOLTAGES

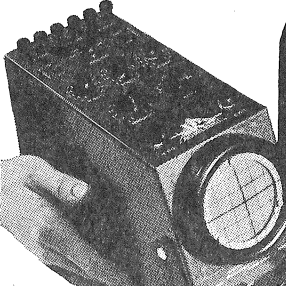
Voltage ratings have been extended for several standard paper and oil-filled capacitor types made by *Aerovox Corp.*, New Bedford, Mass., in order to meet the elevated voltages encountered in television receivers as



well as in cathode-ray oscilloscopes.

Series 84 tubular paper capacitors are made in ratings up to 10,000 d.c.

(Continued on page 27)



HERE'S THE NEW
INDUSTRIAL and TELEVISION
POCKETSCOPE
MODEL S-II-A

by **WATERMAN!** An OSCILLOSCOPE of UNUSUAL VERSATILITY, UTILITY and PERFORMANCE

A 3 INCH OSCILLOSCOPE for MEASURING AC and DC!

AMPLIFIERS for vertical and horizontal deflection as well as intensity
... Linear time sweep from 4-cycles to 50-kc with blanking of return trace
... Sensitivity up to 100 mv in ... Fidelity up to 350-kc through amplifiers
... Attenuators for AC and for DC ... Push-pull amplifiers
... Anti-astigmatic centering controls ... Trace expansion for detail observations. Completely stable regarding line voltage fluctuations and manipulations of controls, either internal or external

\$99 F. O. B., PHILA.

Chassis completely insulated from input circuits assures safety in industrial applications
... Direct connections to deflecting plates and intensity grids from rear ... Retractable light shield ... Detachable graph screen ... Handle ... Functional layout of controls.

8¾ lbs. 11" x 7" x 5"

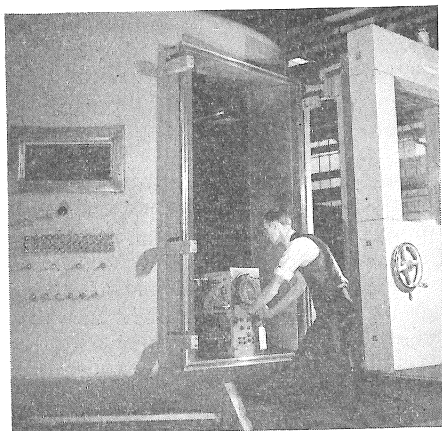


WATERMAN PRODUCTS CO., INC.
PHILADELPHIA 25, PA.

Industrial Review

Weather Test Chamber

Part of the equipment for a radar unit to be used aboard U.S. Navy warships is put into the test chamber at the *Westinghouse Electric Corp.* Ra-



dar and communications units built by *Westinghouse Industrial Electronics Division* for both military and commercial use are given tests under conditions encountered in the Arctic regions as well as in the tropics.

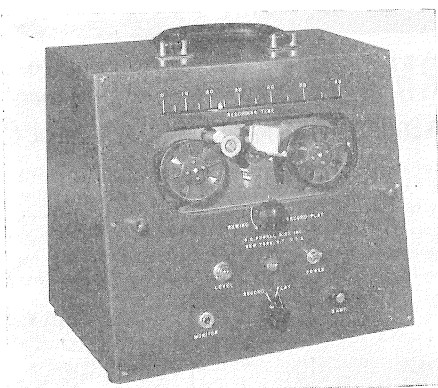
Temperatures from 75° F. below zero to 200° above zero can be simulated in the specially designed chamber. In addition pressure controls make possible the testing of aircraft equipment under varied atmospheric conditions of altitudes up to 80,000 feet.

* * *

Mass Production

First of five models of wire recorders to be put into mass production by the *WiRecorder Corp.* of Detroit will be the Model B Recorder shown here.

Planned for general commercial use by recording studios, radio stations,



schools, theaters, and industrial plants, the instrument is interchange-

able with most sound-on-disc and sound-on-film recording equipment and can be used with any suitable amplifying system already in operation, not duplicating any parts of such a system.

Employing stainless steel wire, Model B features a capstan drive which keeps wire speed constant, magnetic clutches which keep wire tension constant, a cam-operated recording head and safety switches.

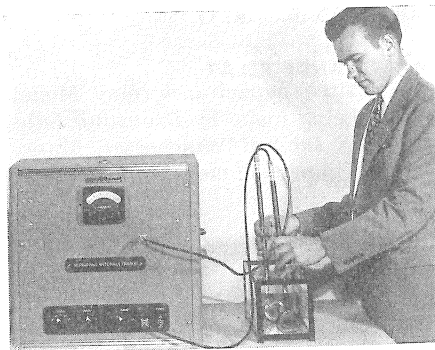
R. C. Powell and Co., Inc., New York, are sales representatives for the *WiRecorder Corp.* and will supply further data.

* * *

Materials Tester

Designed to indicate presence of voids, cracks, porosity, laminations, poor bonds and other internal flaws in metals, plastics and ceramics, an ultrasonic materials tester has been introduced by the Special Products Division of the *General Electric Co.*

The device sends a beam of ultrasonic waves through the specimen be-



ing tested, with changes in the amount of energy transmitted through the specimen serving as an indication of the presence and extent of flaws. Portable and self-contained, the tester provides a direct reading.

* * *

Enters Television

General Instrument Corp., Elizabeth, N. J., largest independent producer of radio components and automatic record changers, has announced its entry into the television field through the facilities of its wholly-owned subsidiary, the *F. W. Sickles Co.*, Chicopee, Mass.

"Special manufacturing techniques are already under way which permit uniform windings to control and assure the rectangular patterns required for horizontal and vertical deflection

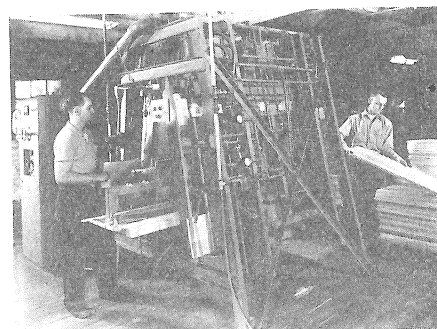
sweeps in both the direct viewing and projection tubes of current and future receiver designs," Richard E. Laux, executive vice-president of *General Instrument* and president of *Sickles*, stated.

He said the companies' business would be substantially augmented as a result of these developments, pointing out that production of television parts on an economical mass production basis is a further step in popularizing television.

* * *

R.F. Gluing Press

A radio-frequency operated edge gluing press and dielectric heating unit for use in the furniture industry has been developed by *Raytheon*



Manufacturing Co. in their Industrial Electronics Division, Waltham, Mass.

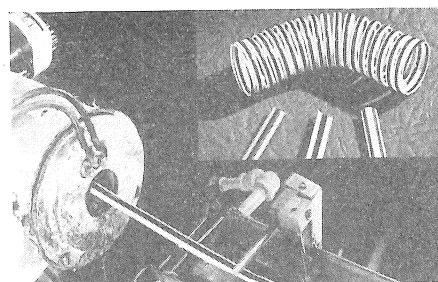
The first installation of the complete equipment at the *Heywood-Wakefield* factory at Gardner, Mass., is shown here.

High-frequency energy from the Raytherm unit is carried by wire to the edge gluing press. Because dielectric heating is generated within the wood core itself, no clamps are necessary and the glue dries within 30 to 50 seconds, depending on the size of the panel.

* * *

Color Extrusion

A new process for the production of exactly controlled multiple-color extrusion of thermoplastics in a single operation, to be known as Spectro-Line extrusion, has been developed by



Schwab and Frank, Inc., 2941 E. Warren Ave., Detroit 7, Mich.

While no details have been disclosed, pending issuance of patents, the new process is said to achieve multiplicity of color with precise control

over color spacing, placement and volume before the thermoplastic materials leave the extrusion machine.

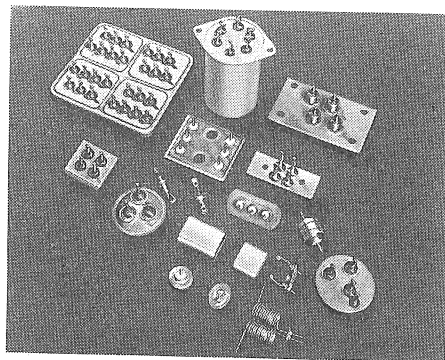
* * *

Hermetic Seals

An exclusive method of producing hermetic seals in a combination of new metal and glass for unrestricted use has been evolved by *Hermetic Seal Products Co.*

By the new process, an unlimited variety of shapes in multiple headers can be turned out with as many terminals as desired molded into a cover unit, at a 75 per-cent saving in material costs.

Hermico-Glass headers possess a matched coefficient of expansion and are vacuum tight, having a permanent chemical bond between metal and glass. Their resistance is over 10,000 megohms between body and terminals



or between terminals.

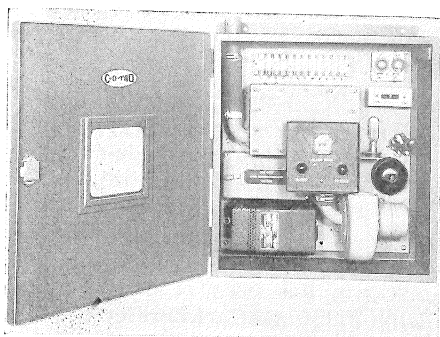
Complete information can be obtained from *Hermetic Seal Products Co.*, 414-418 Morris Ave., Newark 3, N. J.

* * *

Smoke Detector

An industrial smoke detector, the first to be fully approved by the Underwriters' Laboratories, is being produced by the *C-O-Two Fire Equipment Co.*

With an enclosed light beam, the device operates on the principle of light reflected by smoke particles on to a photoelectric cell. Air samples



are continuously drawn into a detecting chamber where, at the first sign of smoke, a red smoke-indicating

lamp is automatically lighted and an alarm sounds.

Further data may be obtained by addressing *C-O-Two Fire Equipment Co.*, P. O. Box 390, Newark 1, N. J.

* * *

Geiger Housings

A special drilling job is performed on the housings for Geiger-Mueller



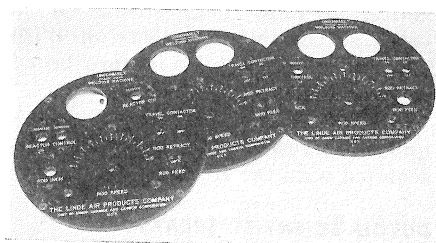
counters by a machinist at the Mount Vernon, N. Y., plant of *North American Philips Co.*

* * *

Acromark Engraving

Efficient and attractive engraving of plastics and other materials, including stainless steel and brass, is made possible by the equipment of the *Acromark Co.*, Elizabeth, N. J.

In the engraving of dials, such as shown here, the dial serves as an attractive front for an electric welding machine unit, with the panel carrying



all the required markings for the control of the machine.

* * *

Divco Developments

New products for the electrical, manufacturing and maintenance field, developed during the past year by the research staff of *Division Lead Co.*, have been announced.

Among these are *Divco* Type F wire stripper, for the cold removal of Formex and Formvar insulation, and #171 wire stripper, for the cold removal of all baked insulations. Both leave the wire leads chemically clean and free of all foreign material, making tinning possible without the use of any flux.

Divco Rosin Fluxes represent the accomplishment of "homogenizing" rosin with any solvent. The homogenizing process completely eliminates

all of the bothersome factors which have heretofore created an obstacle in the use of rosin flux, such as rapid evaporation, settling, separating or crystallizing while in use or storage.

Reflecting a new process of combining resins to an effectiveness not heretofore known by the trade, *Divco* 40/60 #180 Rosin Core Solder makes it easy to solder either clean or oxidized brass, cadmium, copper, galvanized iron, nickel, steel, tin, and zinc.

Additional information on these developments may be obtained from *Division Lead Co.*, 836 W. Kinzie St., Chicago 22, Ill.



NEW!

How to apply the methods or measurements of Radio-Frequency Heating to your industrial, engineering or scientific problems.

THEORY AND APPLICATION OF RADIO-FREQUENCY HEATING

By George H. Brown, Ph.D., E. E. Fellow, I.R.E. Member, A.I.E.E. Research Engineer, RCA Laboratories, Princeton, N. J. Section head in charge of radio-frequency heating and antenna research.

and
Cyril N. Hoyler, M.S. Senior Member, I.R.E. Member technical staff, RCA Laboratories, Princeton, N. J. Formerly Professor and Head of Physics Dept., Moravian College.

and
Rudolph A. Bierwirth, M.S. Member, I.R.E. Chief Engineer, Sound Incorporated, Chicago. Formerly Research Engineer, RCA Laboratories.

This important new book clearly describes and fully explains how radio-frequency heating is used in metallurgy, bacteriology, chemistry and electrical engineering—in the processing of plastics, plywood, furniture, textiles, pharmaceutical preparations, food, rubber, etc.—in the case-hardening of steel, the bonding of thermoplastic sheets, the drying of penicillin, the determination of the properties of electrical conductors and chemical compounds—and in a host of other manufacturing operations and scientific investigations.

All the necessary formulas, factors and methods are presented in convenient graphs, tables and alignment charts—instantly available for direct use in solving actual problems.

From basic principles to actual applications, this book is a logically-developed, complete treatise on radio-frequency heating.

Examine This Great Book FREE

MAIL THIS COUPON

D. VAN NOSTRAND COMPANY, INC.
250 Fourth Avenue, New York 3, N. Y.

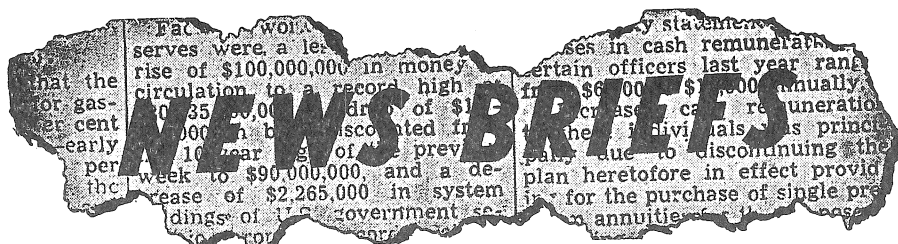
Please send me a copy of **THEORY AND APPLICATION OF RADIO-FREQUENCY HEATING** for examination. Within 10 days I will return the book to you or send you \$6.50 plus a few cents postage.

Name.....

Address.....

City..... Zone..... State.....

R.E.E.—May 1947



WIN I.R.E. AWARDS

Dr. J. R. Pierce, member of the technical staff of *Bell Telephone Laboratories*, New York, was awarded the Morris Liebmann Memorial Prize for 1947 at the recent annual banquet of the I.R.E. in New York.

Made at the same time was the 1946 award, which was granted to Dr. Albert Rose of *R.C.A. Laboratories*, Princeton, N. J. In addition, the election of 25 scientists and engineers to Fellowships in the Institute was announced.

Dr. Rose received the Liebmann prize for his work on the Image Orthicon television picture tube, while Dr. Pierce, engaged in work on high-frequency tubes, won the award for his specific development of the travelling wave type of tube.

N.E.C. INVITES PAPERS

Papers on a wide range of subjects are being invited for possible presentation at the 1947 National Electronics Conference, to be held at the Edgewater Beach Hotel in Chicago November 3, 4, and 5.

Material on research, development and application in electronics and allied fields will be included, as well as a limited number of survey papers, giving a general over-all picture of highly specialized fields.

Those interested in submitting papers are asked to send a 100 to 200 word abstract to Dr. G. H. Fett, University of Illinois, Urbana, Ill., to reach him by June 1. Further inquiries should also be addressed to Dr. Fett.

Accepted papers must not be published elsewhere before the Conference. Papers presented at the Conference are expected to be published in the "Proceedings of the National Electronics Conference."

TEST LAB ESTABLISHED

Made necessary by the growing demand for reliable, stable electronic measuring instruments, a new laboratory to test Geiger-Mueller counters and allied equipment has been set up in the Radioactivity Section of the National Bureau of Standards.

Qualities, utility and construction of counters now being manufactured will be tested, in an attempt to bridge the gap between the manufacturer and the user. Purchasers will be

aided in the formulation of specifications, while manufacturers will be assisted by the accumulation of test data and by determining the type of counters necessary to various fields of scientific research.

Because of the lack of uniform types and design of the counters now becoming available, no attempt can be made at present to set up standard specifications for them, and the uniqueness of each instrument now being manufactured controls the immediate program outlined for the new laboratory. It is expected that co-operation between the laboratory, purchasers and manufacturers will gradually achieve a background of experimental and operational data leading to standard types of equipment.

OLYMPIC OFFICER NAMED

Appointment of Ralph H. Langley as vice-president in charge of engineering of *Olympic Radio and Television, Inc.*, has been announced.

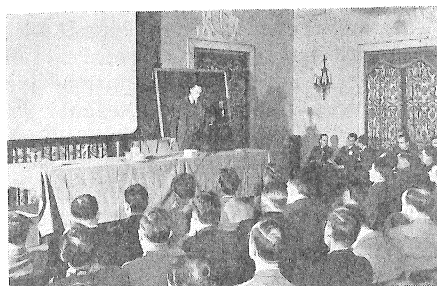
A member of the firm since October, 1946, Mr. Langley will be responsible for the development of *Olympic's* FM and television program. He has been active in radio engineering for 30 years, starting with the *Marconi Wireless and Telegraph Co.* before broadcasting days.

During the war he contributed to important research on radar while associated with the *Hazeltine Co.*

DUTCH SCIENTIST SPEAKS

H. Rinia, co-director of *Philips Laboratories* at Eindhoven, Holland, addressed members of the Institute of Radio Engineers at the recent New York meeting, describing new *Philips* developments in television.

He pointed out that at the Holland laboratories, which constitute one of the world's largest research institu-



tions, a 2.5 inch cathode-ray tube has been combined with a mirror system

to project a television image on a 12 x 16 inch screen. Improvements over previous arrangements of this type have been brought about by increasing tube-screen and mirror efficiencies.

NEW LITERATURE

R/C Rotonoid

The new R/C Rotonoid is described in a four-page bulletin just announced by the *Radio Condenser Co.*, Camden, N.J. Details of construction, possible variables and suggested applications are included.

Infra-Red Parade

A brochure entitled "Infra-Red Parade" and discussing infra-red heating and industrial lighting equipment may be obtained by writing *The Fostoria Pressed Steel Corp.*, Fostoria, Ohio.

"Die-Less Duplicating"

O'Neil-Irwin Manufacturing Co., Lake City, Minnesota, producers of Di-Acro precision machines, have issued



a new 40-page catalog, No. 46-11, containing recent material on "Die-Less Duplicating" in various industries. This booklet may be obtained by writing direct to the manufacturer.

Electronic Tube Data

An "Easy Guide to Electronic Tube Data," compounded by *Westinghouse Electric Corp.*, facilitates the selection of replacement tubes for electronic devices. Tubes are listed according to "family" or class—Phototubes, Pliotrons, Thyratrons, Ignitrons, Kenatrons and Planotrons. Copies of the booklet (86-020) may be secured from *Westinghouse*, P.O. Box 868, Pittsburgh, Pa.

CATHODE-RAY SPECTROGRAPH

Development of a cathode-ray spectrograph, expected to be valuable in jet engine and rocket research, chemical and industrial plants, radar and television, as well as basic scientific research, has been reported by Rudolph Feldt and Carl Berkley of *Allen B. DuMont Laboratories, Inc.*, Passaic, N.J.

The device combines a spectrograph, which breaks a ray of light into a

band of color for chemical analysis, and a cathode-ray tube, which converts the color-band into a single wave-like line on a colored screen, with the pattern of the line indicating the nature of the original compound giving off the light.

Wide application in chemical and industrial process controls, where a continuous indication is required of the state of the product being tested, is foreseen for the instrument by the authors.

ROCKET RESEARCH

General Electric's Aeronautics and Marine Engineering Division and Dunham Laboratory of Electrical Engineering, Yale University, are conducting joint research on a dummy rocket for duplicating flight characteristics of a rocket missile to permit ground testing of guided missile controls, it has been announced.

The flight simulator will couple an intricate calculating machine with a mechanical arrangement of gymbals driven by servomechanisms. Research on controls for the instrument is being conducted at Yale under the direction of Asst. Prof. John L. Bower. This phase of the work is complicated by the fact that the necessarily compact design of a rocket missile and the tremendous forces acting upon it in flight, which may amount to millions of horsepower, require controls which are exceedingly rapid in response.

URNS TO CONSULTING

Arthur J. Sanial has resigned as chief engineer of the *Atlas Sound Corp.* and is devoting his full time to consulting engineering in loudspeaker and sound system design and measurement. Mr. Sanial has been connected with the engineering and manufacturing phases of sound and radio for 25 years. His office is located in Flushing, N. Y.

ACCELEROMETER

Aiding *Westinghouse* shock-testing engineers in the measurement of ultra-high, split-second movement is a compact crystal accelerometer, an accurate measure of shock forces with accelerations up to 6000 g., and higher with less accuracy.

The crystal acceleration detector makes use of the piezoelectric phenomena found in quartz crystals, with a change in force on the crystal surfaces causing a charge to appear on the surfaces. The amount of charge is directly proportional to the change in force exerted on the crystals and, therefore, to the acceleration.

Weighing half a pound, the device is small enough to be carried easily in a coat pocket. Accelerations up to

8000 times gravitational acceleration can be measured at frequencies up to 10,000 cycles per second.

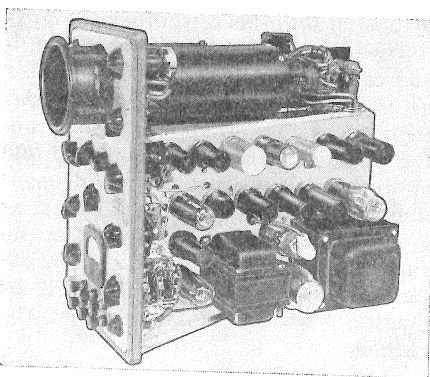
New Products

(Continued from page 23)

working volts, while the midget-can Series 89 and the round-can Series 12 and 14 are available in extended voltage ratings from 3500 to 7500. As a safeguard, Series 14 is produced in the double-ended design or with pillar terminals at either end and with two adjustable ring mountings.

R.C.A. OSCILLOSCOPE

The first instrument of its size to meet laboratory requirements for accuracy, Type WO-79A, a portable 3-inch oscilloscope, is being produced by



R.C.A. Engineering Products Department, Camden, N. J.

Major electrical components of this unit include calibrated horizontal and vertical input attenuators, high-gain horizontal and vertical amplifiers, a synchronizing amplifier, a time-base oscillator and sweep generator, intensifying amplifier, low voltage and high voltage power supplies, and a 3-inch high-contrast cathode-ray oscilloscope.

NEW D. C. RELAY

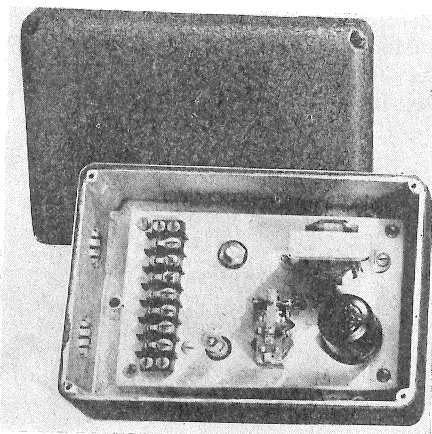
Combining the best features of the conventional telephone-type relay with the small size and light weight of relays developed for aircraft use in the war, Type "J" relay is announced by *C. P. Clare and Co., 4719 W. Sunnyside Ave., Chicago 30.*

Most important of the new features is the use of independent twin contacts in which the possibility of contact failure is reduced to the practical limit. The device is made in both single and double-arm types, with a maximum of 10 springs on a single-arm relay, 20 on a double-arm relay.

RELAY SWITCH

An electronic relay switch, which provides a means of turning an electrical current off and on where it is

impossible to provide a direct electrical contact to carry the required



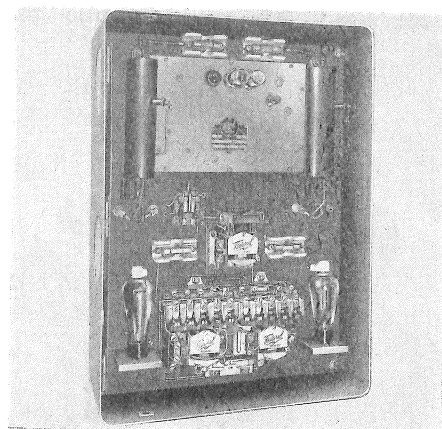
load, is in production at *Special Products Co., Silver Spring, Md.*

The *Speco-Rhein* switch may be used as a liquid level control without the use of a float to increase the life of sensitive limit switches, feeler arms or water type relays. It is especially adaptable for use with combustibles because of the low voltage and microamperes of current necessary for operation.

MOTOR CONTROL

Two models of an electronic motor control for operating d.c. motors from a.c. power have been announced by *Federal Electric Products Co., Newark, N. J.* One, a general purpose, reversing type, may be applied with a 2 h.p., 230 volt d.c. motor, while the second is a special control for an abrasive M-3 surface grinder.

The *Federal* control, result of five years of research and development,



can closely regulate motor speed to provide an almost flat speed torque curve with changes in load having little effect on speed. For any speed setting, performance is practically equal to that of a synchronous motor even with a suddenly applied load.

H.F. VOLTMETER

To meet the need for improved measuring equipment for the frequen-

cy range from 500 kc. to 500 mc., the *Alfred W. Barber Laboratories* are producing Model 32 high frequency electronic voltmeter.

Model 32 is equipped with a radio frequency probe having the extremely low input capacity of $\frac{3}{4}$ μ fd. and of-



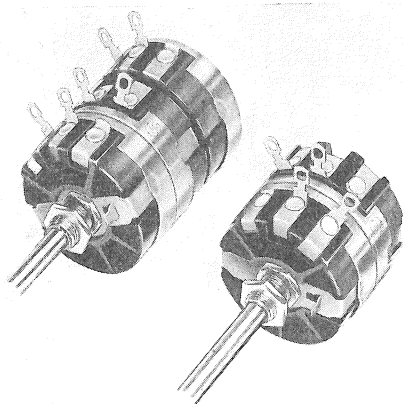
fers better than 5% of full scale accuracy on all ranges and sinusoidal voltages.

Descriptive bulletins may be obtained by writing to *Alfred W. Barber Laboratories*, 34-14 Francis Lewis Blvd., Flushing, N. Y.

L-PADS AND T-PADS

Covering impedance ranges from 8 to 600 ohms, wire-wound T-Pads and L-Pads for sound system are being manufactured by *General Electric's* Electronics Department.

The T-Pads may be used as variable attenuators in stable line impedance while the L-Pads have application as



individual volume controls for multiple speakers or as attenuation controls for constant impedance at either the source or load.

Further information or specification sheets may be obtained from the Specialty Division, *G-E Electronics Department*, Wolf Street Plant, Syracuse.

Experimental Receiver

(Continued from page 15)

pedance of the triodes at high frequencies, back-coupling is employed in the asymmetric circuit. This causes a reversal of damping in that circuit or, in other words, an increase in the input impedance of the tubes and with it an increase of the auxiliary voltage obtained on the input electrodes.

If the reversal of the damping is made large enough (the back-coupling strong enough) the circuit itself begins to oscillate, and it oscillates at the frequency to which the asymmetric input circuit is tuned, i.e. the frequency of the auxiliary voltage.

A separate oscillator is then not needed for the excitation of this auxiliary voltage. As far as the conversion effect of the triodes is concerned it makes no difference whether the auxiliary voltage between grid and cathode comes from a separate oscillator or whether it is excited by the triodes themselves. The mixing action is determined exclusively by the magnitude of the auxiliary voltage and the non-linearity of the i_p-e_g characteristic.

The back-coupling mentioned in the case of a triode can be obtained in the familiar way by connecting a self-induction between the anode and the cathode.

In the push-pull mixing stage the self-induction is introduced in the manner shown in principle in Fig. 4. The equal-phased circuit, which is tuned to the desired oscillator frequency by means of the variable impedance Z , is now so strongly regenerated by the self-induction L_2 as to cause oscillation.

It must be pointed out that the push-pull circuit can also be regenerated in a similar manner. For that purpose the two self-inductions L_3 shown with dotted lines in Fig. 4 have to be placed in the anode circuit. In this way it is possible to obtain a stronger excitation of the signal delivered by the aerial, and thus a better relation between signal and noise. The degree of back-coupling can be chosen different for the push-pull circuit and for the asymmetric circuit, but L_2 has no effect on the push-pull circuit. This is important because the back-coupling for the push-pull circuit may not, of course, be made so great that oscillation (with signal frequency) occurs in that circuit.

Ratio of Signal Intensity to Noise

The fact that a separate oscillator tube can be omitted constitutes of itself a welcome simplification of the connections. Still more important is the fact that an improvement in the

relation between signal intensity and noise is thereby obtained. This can easily be explained. In the anode current of an oscillator tube, as is the case with every tube, there is a noise with a continuous frequency spectrum. The circuit connected with the anode circuit of the oscillator tube, which is tuned to the oscillator frequency, acts as a kind of filter which passes chiefly the oscillator frequency but to a certain extent also the neighboring signal frequency and, to a smaller extent, the much lower intermediate frequency.

The components of the noise with those frequencies are thus also applied more or less intensely to the mixing tube as input voltage together with the oscillator voltage proper. The noise at signal frequency is then also converted with the signal, the noise at intermediate frequency is directly amplified, and both therefore give rise to an increased level of noise in the intermediate-frequency output voltage of the mixing tube.

It is clear that with the omission of the separate oscillator tube this extra contribution to the noise is eliminated.

The above-described effect of the noise of an oscillator tube is stronger accordingly as the intermediate frequency chosen is lower. This means that the signal frequency lies very close to the oscillator frequency, so that the component of the noise at the signal frequency is passed by the tuned circuit of the oscillator almost in full strength. From this point of view, therefore, the intermediate frequency should be as high as possible.

Although in our case, due to the omission of the oscillator tube and the noises inherent therein, this consideration is no longer applicable, as far as the choice of the intermediate frequency is concerned one reaches the same conclusion. In the above considerations it was tacitly assumed that the symmetry of the push-pull stage is complete, so that the balanced and asymmetric circuits do not affect each other at all. In practice there will always be a certain asymmetry and consequently a coupling between the two circuits. If, now, the characteristic frequencies of the two circuits lie close together (i.e. if the intermediate frequency is low), the oscillation of one circuit causes resonances in the other, with the further consequence of unequal voltages on the two tubes, etc. The intermediate frequency may not, therefore, be chosen too low. Upon closer consideration it is found that it should amount at least to $1/20$ of the signal frequency in order to render the coupling in question harmless. The receiver described here works with an intermediate frequency of 18 mc., the condition just given is therefore satis-

fied up to a signal frequency of 360 mc., i.e. a wavelength of 83 cm.

In Fig. 2 a diagram is given of the complete connections of the mixing stage, while Fig. 4 shows a photograph of the stage when constructed.

To the grids of the two button triodes used as mixing tubes a Lecher system is connected, which together with a condenser (C_1) forms the push-pull input circuit of the mixing stage. The capacities C_2 , C_3 serve only for separating the d.c. voltage situation of the two grids. The desired regeneration of the push-pull input circuit is obtained by the self-induction L_2 introduced between the anodes.

The asymmetric input circuit of the mixing stage is formed by the two conductors of the Lecher system, which for this purpose are to be considered simply as two separate impedances through which rectified currents pass. This input circuit is closed by the chassis, since the sliding short-circuiting bridge of the Lecher system is connected directly with the chassis. The back-coupling for the equiphased oscillation is accomplished by the self-induction L_3 connected to the middle of L_2 (to which has to be added the two halves of L_2 to be considered as connected in parallel). The magnitude of this self-induction, however, not only determines the degree of back-coupling but also has an influence on the frequency generated. Since the adjustment of the back-coupling is not very critical, advantage can be taken of the influence mentioned to regulate the oscillator frequency more exactly by varying L_3 . Since, however, a continuously variable self-induction is less easy to realize, for this purpose a rotating condenser (C_6) is introduced in series with L_3 .

The tuning of the push-pull and asymmetric circuits is now accomplished as follows: After L_3 and C_6 have been so chosen that sufficient regeneration has been obtained for the occurrence of oscillation in the asymmetric circuit, that circuit is tuned approximately to the oscillator frequency by moving the short-circuiting bridge of the Lecher system. By a correct choice of C_1 the push-pull circuit is then tuned approximately to the signal frequency, while the tuning is obtained again by a slight movement of the short-circuiting bridge, and the fine tuning to the oscillator frequency is finally obtained with C_6 . This rather laborious manipulation constitutes no objection in our case, since the receiver always remains set on the same wavelength. Finally, there is the intermediate-frequency circuit. This consists of the self-induction L_4 and the capacity C_7 . Between the triodes

and this circuit the high-frequency choke coils $RFC1$ and 2 are connected in order to prevent the high-frequency circuits from being affected by L_4 - C_7 . Conversely, the capacities C_4 , C_5 , which have a high impedance for the intermediate frequency and a low impedance for the signal and oscillator frequency, provide that the circuit L_4 - C_7 is not practically short-circuited by the small self-induction of $RFC1$ and 2.

Remaining Parts of the Receiver

The intermediate-frequency amplifier consists of a number of stages with EF51 tubes. The tubes are coupled by band filters, but in one stage connections are used like those described in the article about the transmitter of this installation. By this means it was possible (as in the case of the transmitter) to divide the receiver into two parts in this stage, thus at the middle point of the intermediate-frequency amplifier, and to house the two parts in two separate panels without it being necessary to shield the connections between the panels. The two panels may be seen in the photograph of Fig. 5.

After the intermediate-frequency amplification a limiter is applied to the signal, as is customary in receivers for frequency-modulated signals. This consists of two tubes provided with grid condenser and leak resistance. When the amplitude of the a.c. voltage on the grid of a tube in these connections increases, the grid becomes more negative due to the occurrence of grid detection. This reduces the anode current and, in spite of the increased input voltage, the output voltage of the tube shows little or no increase.

In this way any amplitude modulation which may still be present in the frequency-modulated signals, and especially the noise present in that form, is suppressed to a large extent. The output voltage of the first limiter tube, which is already quite constant, is chosen so high that the second tube is adjusted at the point of the characteristic most favorable for the limiting effect. A total suppression factor of 100 is thereby attained, i.e. the depth of the amplitude modulation of the signal at the output of the limiter is 100 times smaller than at the input. Receivers for amplitude-modulated signals are usually equipped with an automatic volume control, with which a part of the output voltage of the last intermediate-frequency amplifier tube is rectified and used to regulate the grid bias of one or more of the preceding amplifier tubes.

In the case of a frequency-modulation receiver, when the limiter has a

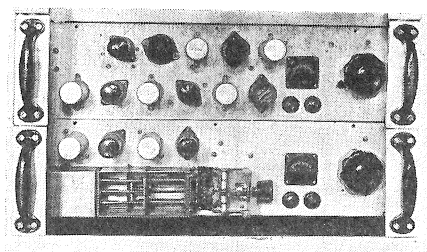


Fig. 5. The receiver is assembled in two panels, which can be slid in and out of the bay containing the whole transmitter.

sufficiently large suppression factor such a volume control may be omitted, since the limiter already provides for a practically constant output voltage. In our case, therefore, all the tubes of the intermediate-frequency amplifier work with constant negative grid bias. Account must then be taken, however, of the possibility that the last tube of the amplifier may be overloaded and damaged by a strong signal. In order to prevent this, that tube, as well as the tubes of the limiter, is provided with a grid condenser and leak resistance in such a way that the tube simply begins of itself to act as a limiter as soon as the signal exceeds the permissible strength.

The only result of an increase in the signal then is that there is a stronger suppression of any amplitude modulation which may be present, which at

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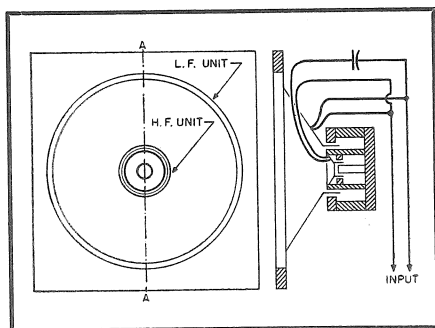
the most can but improve the quality of reception.

Following the limiter there comes finally a normal frequency detector and a low-frequency amplifier tube. The low-frequency signal obtained is conducted *via* a transformer to the cable leading to the carrier-telephony apparatus.

Loudspeakers

(Continued from page 5)

with the preceding data, an initial throat area of two square inches would result in a total length of over 12 feet to reach the theoretically necessary flared opening of approximately 11.7 feet in diameter.



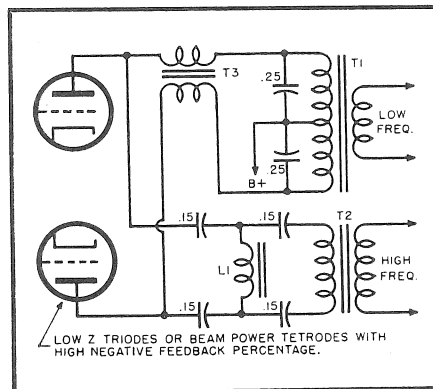
Courtesy of RCA Review
Fig. 5. Duo-cone loudspeaker developed by Olson and Preston.

The use of horn-loading not only improves the efficiency of the system but also aids in decreasing certain types of distortion. The acoustic impedance of a direct radiator speaker is mismatched with the air to a very considerable extent. This mismatch is particularly serious at very low frequencies. The relatively low impedance into which a direct radiator speaker works is such as to encourage resonant wave trains following shock excitation. This is comparable to a band pass tuned filter which will oscillate upon shock excitation when terminated improperly. In experimental setups a direct radiator speaker may be used as the tank circuit in an oscillator consisting of a microphone and an audio amplifier. Such, in fact, is the origin of many acoustic feedback effects. Correct horn-loading is a great aid in minimizing hangover responses from transient excitation. The waveforms of music consist almost entirely of essentially transient impulses. The damping of many musical instruments is controllable by the performer. Staccato notes are common, damped waveforms are common; long, sustained notes partaking of a truly non-transient nature are relatively rare. Consequently the performance of a loudspeaker in response to transients is extremely important in high quality systems.

The duo-cone direct radiator speaker described earlier was tested for square wave response with a specially designed microphone. The results were very comparable to the square wave response from high quality audio amplifiers. The input was a square wave current. Transient response in a multiple speaker system is usually poorest in the crossover region. The crossover in the Olson and Preston duo-cone is 1000 c.p.s. yet the excellent square wave response was obtained at a fundamental frequency of 900 c.p.s. Most loudspeaker systems will produce nothing remotely resembling acoustic square waves.

In large theater installations horn-loading is invariably applied to both woofer and tweeter speakers. With such facilities nearly perfect results are obtainable. The real problem is to produce comparable characteristics in a relatively small space. Since it is possible with careful designing to fold the horns without great loss, the criterion of success may be expressed in cubic content. The Klipschorn, illustrated in Fig. 1, occupies only 15 cubic feet of space, yet reproduces frequencies down to 30 c.p.s. Comparable theater systems will occupy from 60 to several hundred cubic feet. The enclosure is designed to take advantage of corner placement so that the walls function as extensions of the horn. This enclosure uses a 15-inch cone type driver. With the driver mounted on a large flat baffle, the efficiency is approximately 2%, which is normal for better than average speakers at low frequencies. Comparable measurements in the Klipschorn enclosure showed 30% efficiency. These measurements were checked by comparing similar drivers—one on a large flat baffle, the other in the horn-loading enclosure. Losses were introduced in the power fed to the horn-loaded unit until the output from each was observed as being approximately equal. The insertion loss required was 15 db. which checks out

Fig. 6. Electrical crossover network designed by Klipsch for use with his speaker system.



very well with the efficiency measurements.

The crossover frequency used with the Klipschorn is around 500 c.p.s. This suggests the possibility of introducing insertion losses as partial compensation for the constant amplitude record characteristic. It also suggests the use of a crystal pickup, which responds perfectly to constant amplitude recorded signals, to feed the low-frequency driver. A magnetic generator pickup, responding perfectly to the constant velocity portion of the record characteristic, would then be used to feed the high-frequency unit through a separate amplifier. The use of such a dual pickup arrangement would provide a natural dividing network at the input. One advantage would be that the system would have an inherent automatic self-adjustment to compensate for whatever crossover frequency appeared on a recording chosen at random. Work in progress along these lines has shown sufficient promise to warrant further investigation.

One reason for the relatively low crossover frequency in the Klipschorn design is the fact that characteristics in the region of the folds preclude satisfactory transmission at frequencies above 1500 c.p.s. An electrical crossover network for use with his speaker system has been described by Klipsch.⁴ This circuit is shown in Fig. 4, and design details are presented in the referenced paper. Low-cost components are used to produce high-quality results. A particularly interesting feature of the report is the statement that phase relationships appear to have little or no effect, even in the crossover region. No observable change is reported in listening tests with phase relationships shifted back and forth 180 degrees between the two speakers. This may be partially attributable to the relatively low crossover frequency. Most small systems cross over at 1000 to 2000 c.p.s. or higher.

It is unfortunately true that the average commercial phonograph record is not a satisfactory source of high-frequency signal. There are, however, many contemporary recordings capable of taking advantage of the characteristics of wide-range systems. It is usually assumed that no signal of consequence appears on commercial records above approximately 8000 c.p.s. Comparative listening tests show a distinct improvement in the crispness of reproduction when loudspeaker systems extending beyond 10,000 c.p.s. are used. Unfortunately it is not possible to enjoy this wide range except with plastic record materials unless the Dynamic Noise Suppressor developed by Hermon Hosmer Scott or

a similar noise suppressor is used as associated equipment.

The increasing availability of FM facilities is the greatest incentive toward improvement in loudspeaker systems. Few indeed are capable of properly reproducing the full range of live FM programs.

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Miniature Tubes

(Continued from page 8)

Another application for the cathode-coupled stage is shown in Fig. 4C. In this circuit which shows a grounded-grid r.f. amplifier and a cathode-coupled stage following it, the cathode-coupled stage acts as a mixer. The local oscillator signal is injected

	Capacitances ($\mu\text{fd.}$)				Voltages				g_m
	GP	GK	PK		Ep	Esg	Ec		
6J4	4	5.5	.24		150	—	$R_k=100$		12,000
6J6	1.6	2.2	4		100	—	$R_k=50$		5,300
6AK5	.02	4	2		180	120	$R_k=200$		5,100
6C4	1.6	1.8	1.3		250	—	-8.5		2,200

Table 1. Some of the characteristics of the new miniature tubes.

by connecting a portion of the oscillator coil between the grid and ground of the second section of cathode-coupled stage. Normally the grid is tied directly to ground. This little circuit performed well in tests made at Temple University.

These special miniature tubes perform well at frequencies up to 500 megacycles and higher. Consequently they will see wide application in television relay and high-frequency transmission. At these frequencies it is well to utilize a push-pull arrangement, Fig. 5, to lower effective capacity and form a balanced high-frequency circuit.

Appendix I

In broadband high-frequency circuits it is necessary to load tuned circuits with resistors in order to widen the band of frequencies passed. In fact, this load resistor is so low in value the gain of the amplifier is simply:

$$\text{Gain (resonance)} = g_m R_L \dots \dots \dots (1)$$

At other than the resonant frequency there is a reactive component, and the plate load, instead of being simply R_L , becomes an impedance:

$$Z_L = \frac{RX}{\sqrt{R^2 + X^2}} \dots \dots \dots (2)$$

Now, at some frequency on each side of resonance this reactive component X must equal the value of the loading resistor R_L . At this frequency the gain of the stage becomes:

$$\text{Gain} = \frac{g_m R^2}{\sqrt{2} R^2} = \frac{g_m R}{1.414} = .707 g_m R \dots \dots (3)$$

Thus, at the frequency points where the reactive component of the tuned circuit equals the value of the loading resistor the gain of the amplifier is at the 70.7% level of peak gain. The frequency range between the two 70.7% levels, one on each side of the resonant frequency, is generally considered to be the bandwidth of the tuned circuit.

It is apparent that the gain of the stage is directly proportional to the value of the load resistor. However, the size of the load resistor is limited by the X_L and X_C at resonance and the bandwidth of the stage as shown below.

The inductive reactance of the tuned circuit at some point off resonance is:

$$X_L = 2 \pi f_r L \pm 2 \pi \Delta f L \dots \dots \dots (4)$$

where f_r = resonant frequency and Δf = the change in frequency (bandwidth) on one side of the resonant frequency.

The ratio by which the inductive reactance has been changed is:

$$\text{ratio} = \frac{f_r + \Delta f}{f_r} \dots \dots \dots (5)$$

Thus, the inductive reactance at any frequency off resonance is simply X_L at resonance times the ratio by which the frequency has been raised or lowered:

$$X_{L1} = X_L(\text{resonance}) \left(\frac{f_r \pm \Delta f}{f_r} \right) \dots \dots \dots (6)$$

Now, let us derive the equation which shows the capacitive reactance at some frequency off resonance in the same manner:

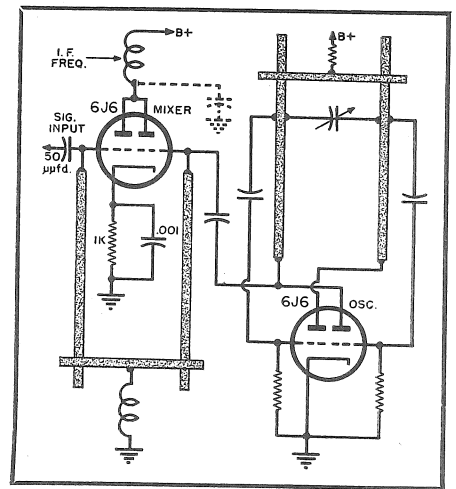


Fig. 5. Push-pull mixer-oscillator using 6J6 dual triodes.

$$X_{C1} = \frac{1}{2 \pi f_r C \pm 2 \pi \Delta f C} \dots \dots \dots (7)$$

$$\text{ratio} = \frac{f_r}{f_r \pm \Delta f} \dots \dots \dots (8)$$

Now, the combined reactance of inductor and capacitor becomes:

$$X_1 = \frac{\left[X_L \left(\frac{f_r \pm \Delta f}{f_r} \right) \right] \left[X_C \left(\frac{f_r}{f_r \pm \Delta f} \right) \right]}{X_L \left(\frac{f_r \pm \Delta f}{f_r} \right) - X_C \left(\frac{f_r}{f_r \pm \Delta f} \right)} \dots (9)$$

However, at the resonant frequency $X_C = X_L$. Let us term the resonant reactance X_r , so that:

$$X_1 = \frac{X_r^2}{X_r \left(\frac{f_r \pm \Delta f}{f_r} - \frac{f_r}{f_r \pm \Delta f} \right)} \dots \dots \dots (10)$$

Also at the 70.7% level, $X_L = R$ or:

$$R = X_r \left[\frac{f_r (f_r \pm \Delta f)}{\Delta f (2f_r \pm \Delta f)} \right] \dots \dots \dots (11)$$

Inasmuch as $\Delta f \ll f_r$ for television wide-band application:

$$R = \frac{X_r f_r^2}{2 \Delta f f_r} = X_r \frac{f_r}{2 \Delta f} \dots \dots \dots (12)$$

This, then, is the basic formula for loading a tuned circuit. Thus, for a given L to C ratio, resonant frequency, and bandwidth, the size of the loading resistor to obtain this bandwidth (between 70.7% levels) can be calculated.

Inasmuch as the value of R_L determines stage gain ($g_m R_L$) we can see that the stage gain is less as the bandwidth requirements are increased. Likewise, the stage gain is increased as the L to C ratio is increased because the size of the loading resistor per given bandwidth is higher (X_r in the formula is high when the inductance is high and the capacity low).

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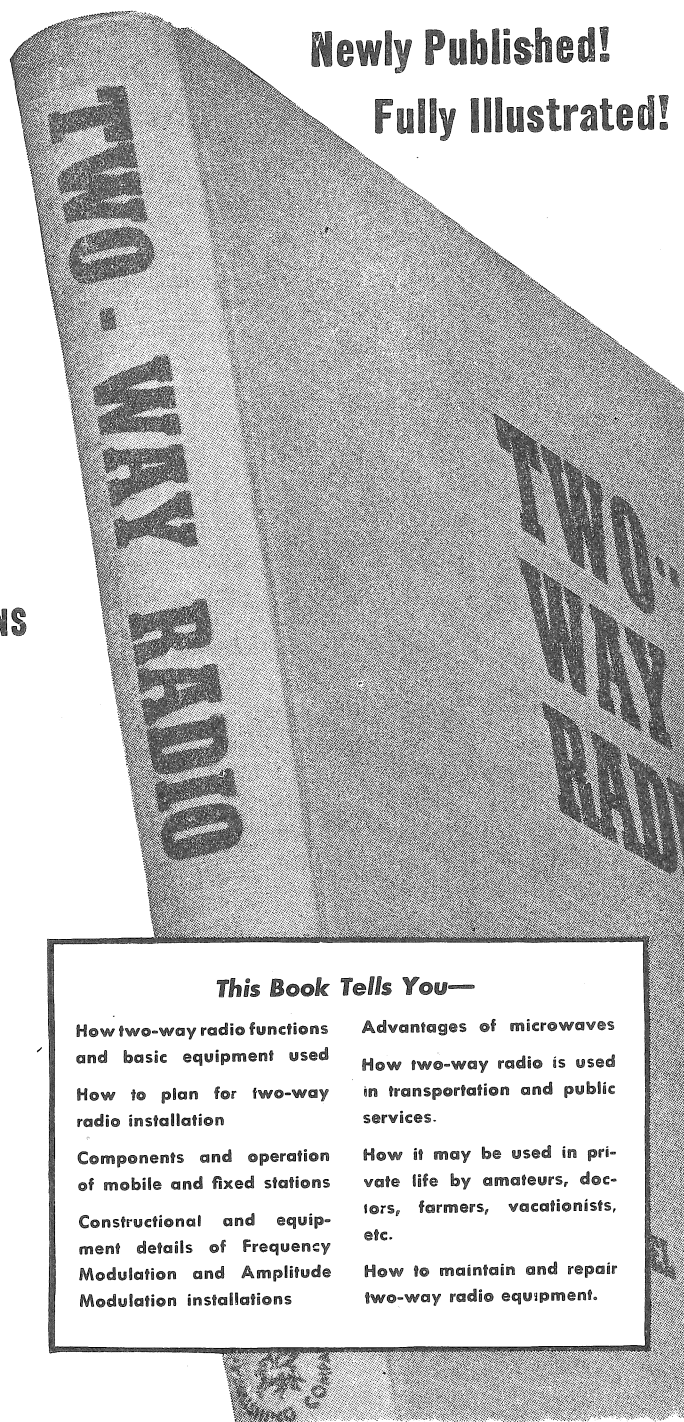
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